Low Cost Shore Protection: Design Criteria, Adverse Impacts, Expected Results and Model Municipal Ordinance

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LOW COST SHORE PROTECTION: DESIGN CRITERIA, ADVERSE IMPACTS, EXPECTED RESULTS, AND MODEL MUNICIPAL ORDINANCE

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for

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CONTENTS

Work Element 4.a.

SHORE EROSION PROTECTION: TYPES OF STRUCTURES AND THEIR RELATIVE SUCCESS IN PREVENTING SHORE LOSSES

General Introduction

The purpose of this section of the report is to discuss the various types of shore protection structures and to determine their relative success in application toward reducing losses due to erosion and recession. Included in the discussion is a brief examination of the dynamics of beach equilibrium. Both structural and non-structural alternatives will be discussed. The focus of attention is on the low cost structures and a variety of non-structural alternatives. Major works undertaken usually at the Federal level will not be discussed. Such structures require significant outlays of money for planning, engineering, and construction and are beyond the economic means of the property owner. It is the express intent to develop a concept that can be adopted by individual property owners as well as local governments.

Shoreline Dynamics

Shoreline stability in any unprotected natural coastal zone is controlled by the supply, transfer, and loss of material (McGill, 1980). In a simple equation sand accumulation at any point on the shore is equal to the amount of sand in the system minus the amount lost downshore and/or the amount lost offshore. Stability of any shore area then is a condition dependent on the active agent of erosion in the shore zone--waves. Rather than being stable for any length of time the beach is in a process of dynamic equilibrium through time unless the natural processes are thrown out of balance by a drastic change in beach material or by storm waves in a 50-100 year event. The supply of sand to the system originates updrift. The sources are streams carrying sediment to the littoral and/or material wasted from the shoreline itself including the sand content of the eroded bluff. A beach may be temporarily eroded by storm waves and then restored by the milder constructional wave. In addition, the erosion and accretion patterns may occur seasonally. The long-term configuration of the beach is totally dependent on supply. For example, the shore will accrete sand and will prograde when the rate of supply of sand exceeds the rate of loss.

The size and character of sediments on a beach are related to the forces to which the beach is exposed and the type of material available at the shore. Most beaches are composed of fine sand, coarse sand, or shingles or gravel (Shore Protection Manual, 1975).

Quite apart from the problem of long-term shoreline evolution lies the issue of whether erosion is more effectively reduced by natural processes or by man-made devices. The superior recuperative powers of unaltered coastal systems are widely recognized. In fact, many believe that investment in areas of critical erosion should be discouraged and we should leave the systems to achieve a state of dynamic equilibrium.

This physical process of erosion has not been perceived as a problem until it has induced an economic impact on either an individual or a community (Kerns, 1980). Where beaches protect shore development it may not be necessary to provide additional works that might interfere with the natural system. One important reason why individual property owners are noticing less beach is due primarily to the fact that updrift structures are trapping sand that would ordinarily be distributed over a longer reach of shoreline. In fact most of the structures built are designed to trap sand. The principal benefit of shore structures is to retain a narrow protective beach derived from the beach sized materials eroded from the bluffs and offering potential protection or, retard to some degree, further recession (Omholt, 1974).

The principal cause of shore damage is development historically occurring along the shore. Many of these structures are now vulnerable to the physical processes of change and will, in time, be destroyed completely. Separate protection over the shore reach of a single property within a larger zone of erosion is difficult and costly. Such protection usually fails at the flanks producing accelerated impact mostly in a downdrfit direction. Development represents an encroachment resulting in monetary loss to storms and the increased cost of shore protection.

Selection of an Appropriate Structure

Because of the tremendous variability of physical and man-related factors, no single protection is considered a best choice. The physical factors include littoral drift, sediment supply, nearshore bottom configuration, and the nature of the bluff material. Man-related factors may include value of the property being protected, presence or absence of other shore protection, and the location of structures with respect to an active bluff or beach.

Unfortunately, the type of protection chosen is limited to the dollars an individual has to invest in a shore protection device. The range is complete. We have seen scrap materials, brush, old cars, appliances as well as well engineered (and expensive) works.

Given the correct tools and information, it should be possible to design a "fool-proof" seawall or groin field which functions as intended without negative side effects. However, each site offers a different set of circumstances creating a need for individual site design. It is not possible to entirely anticipate the particular problems existing at individual sites (Brater et al, 1974).

The owner has five basic choices when considering shore structures:

(1) Pay the high cost of a properly engineered and proven structure,

(2) Sell the property to an unsuspecting buyer,

(3) Develop his own solution,

(4) Do nothing, or

(5) Utilize low cost, temporary designs.

Given the heavy cost of conventional beach protection, the result is a variety of ill-conceived and poorly coordinated private protection schemes which frequently do little more than exacerbate existing problems.

The most effective structures are very expensive, usually greater than $400 per foot of protected shore. The cost of some structures may be as little as $10 per foot but this is for rudimentary works that are not expected to last over time or to sustain a serious storm. In many cases the cost of the structure may exceed the value of the property being protected (U.S. Army, Corps of Engineers, 1977).

Low Cost Structures

As stated in the introduction, the focus of this section is not on the high cost structure. Because of costs the shoreowner is left with the low cost alternative or one of the other choices listed above.

With few exceptions no low cost structure can ensure permanent protection against high lake levels and periodic severe storms. Low cost structures are exposed to forces that they are not designed to handle. The ultimate protection then cannot be provided the property owner at a reasonable cost. The low cost design can experience damage by the five to ten year frequency storm. It cannot be implied that low cost structures or a low cost solution is acceptable or even available for most erosion situations.

In sheltered waters low cost structures are better suited. Such structures are defined by cost; less than $50.00 per front foot for materials and can be installed without the use of heavy equipment, or, less than $125.00 per front foot for materials and placement using heavy construction equipment (Edge, 1976).

Whereas permanent structures are expensive low cost structures have the advantage of low first cost. However, higher maintenance costs and reduced functional life are the consequence. Private shoreline owners need more accurate, reliable information about effective low cost protection methods (Armstrong, 1976).

The Shoreline Erosion Control Demonstration Act of 1974 directed the Secretary of the Army, acting through the Corps of Engineers "to establish and conduct for a period of five years, a national Shoreline Erosion Control and Demonstration Program." The intent of the program is to develop and demonstrate to the public and technical community methods for low cost shore protection. Specifically, these methods are to be developed and demonstrated in sheltered waters. Sheltered waters are defined as those areas where the design breaking wave is less than six feet. In addition, the Act specifically calls for widespread dissemination of the results of this program (Section 54, Shoreline Erosion Control Act of 1974).

Congress found that "because of the importance and increasing interest in the coastal and estuarine zone of the United States, the deterioration of the shoreline within this zone due to erosion, the harm to water quality and to marine life from shoreline erosion, the financial loss to private and public landowners to obtain satisfactory financial and technical assistance to combat such erosion, it is essential to develop, demonstrate, and disseminate information about low cost means to prevent and control shoreline erosion" (Shoreline Erosion Control Demonstration Act of 1974).

Because of the funding available, a great variety of low cost structures have been experimented with. Of greatest interest are those sites and techniques used in the Great Lakes. (See Figures 1-8)

Demonstration project at Port Wing

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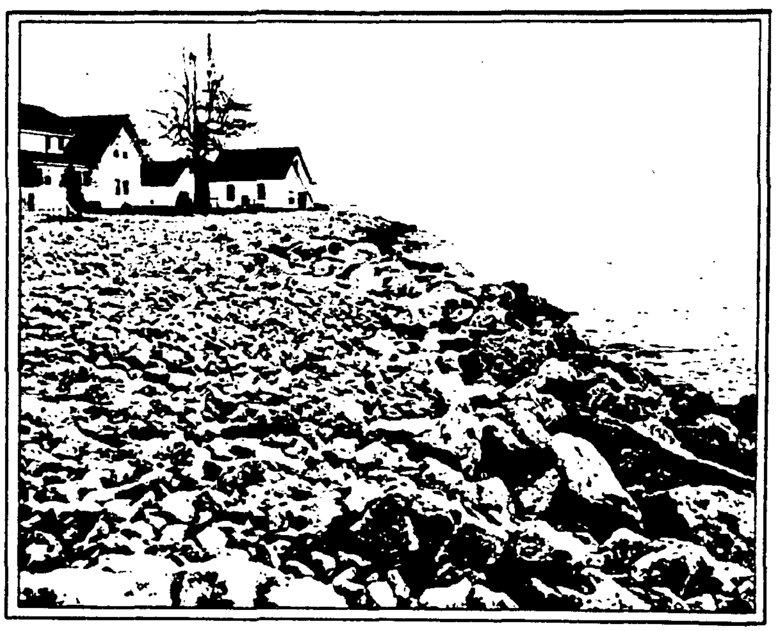
Pt. MI.



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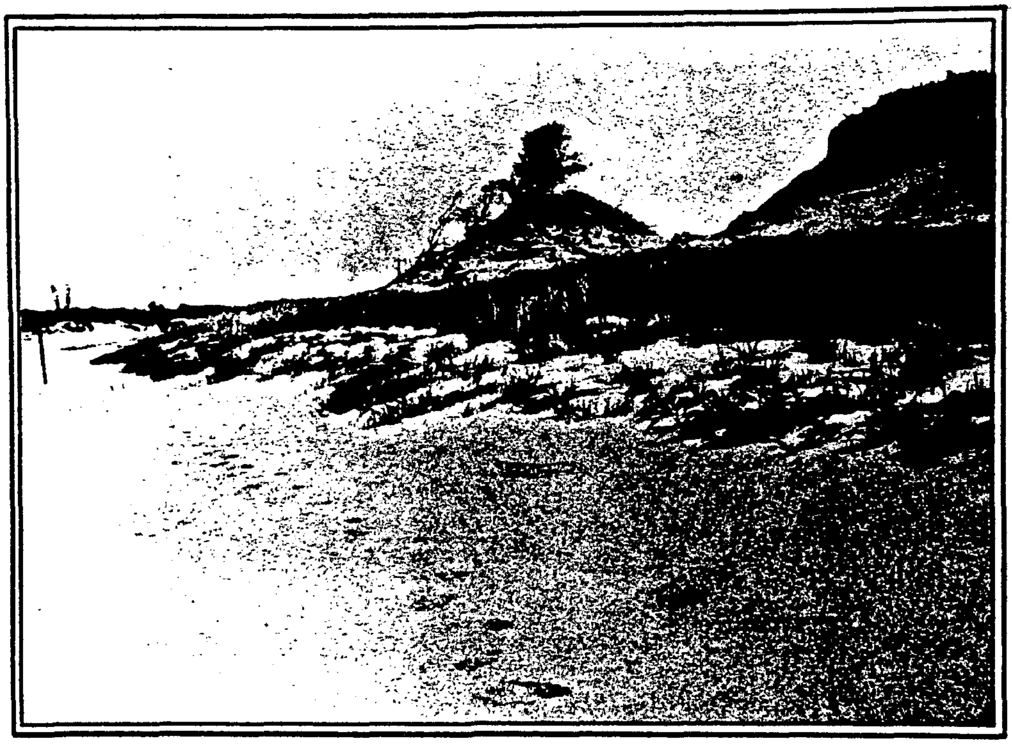

Vegetation site at Ludington State Park

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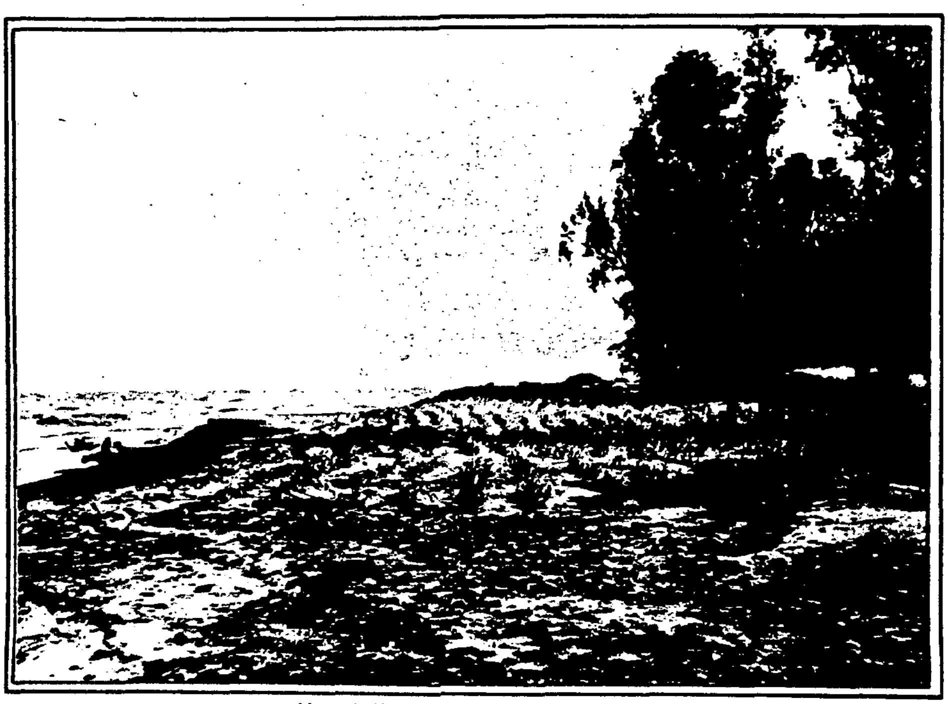

Vegetation site at Presque Isle

Breakwaters at Beach 10, Presque Isle.

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Demonstration project at Geneva State Park

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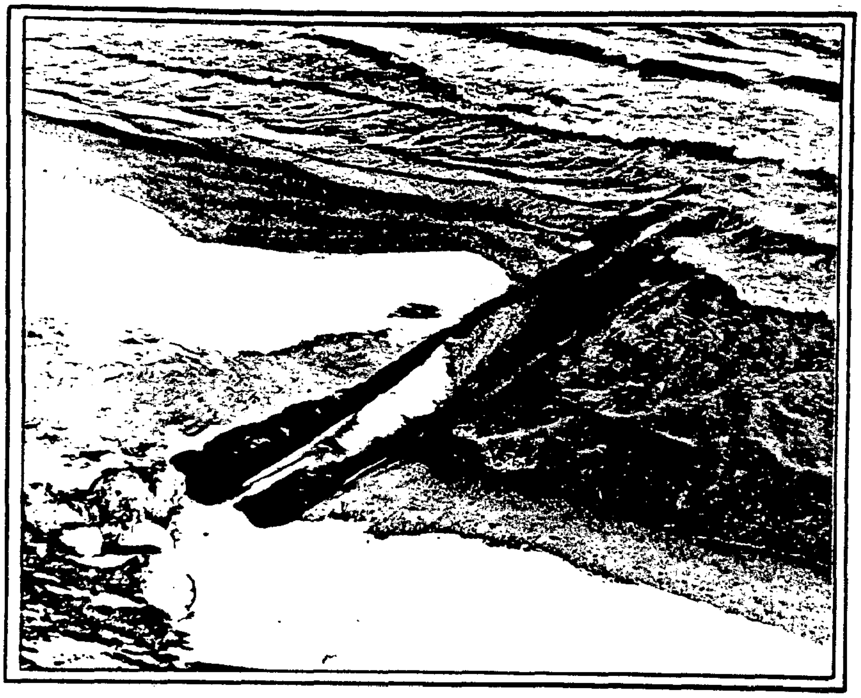

Sand-filled nylon tube groin 3 miles south of Port Sanilac, MI.

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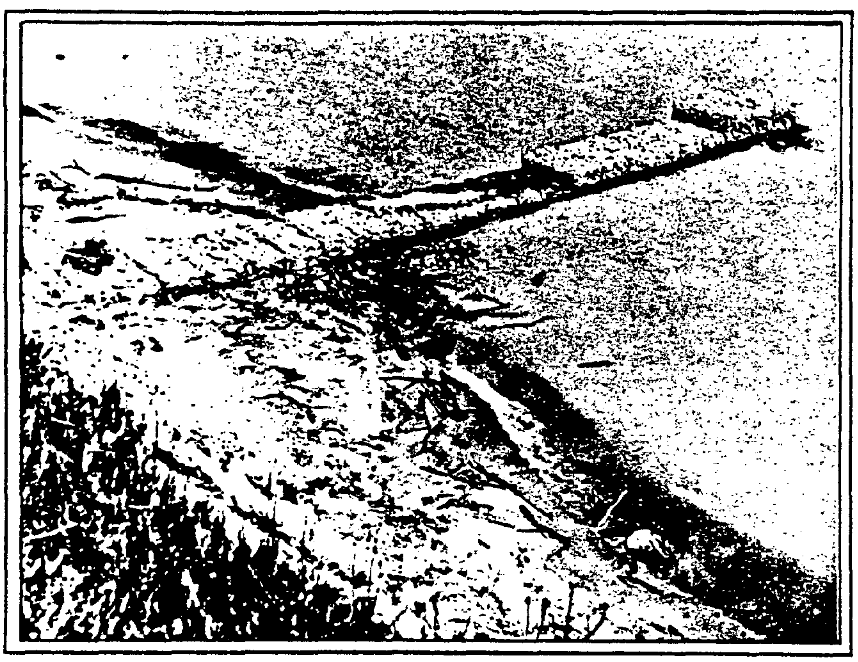


Gabion groin, 3 miles south of Port Sanilac, MI.

8

General Discussion on the Relative Success or Failure of Shore Structures

A failed structure can be defined as one that was subject to extreme damage well within the life of the structure and which, without major repairs, would be a total failure. Conversely, to be successful, a structure must withstand the energy of wave attack over the calculated life of the structure. A full evaluation on relative success can come only after years of observation.

Durability of a shore structure depends on the number of storms, their intensity and duration, as well as soil type, geologic structure of the lake bottom and shore, and the topography of the shoreline. Site specific variables prevent broad comparisons of structural effectiveness (Armstrong, 1976).

A piecemeal approach to solving shore erosion problems is the major cause of continued failure and consequent financial losses (Clemons, GLBC). It is entirely possible to construct a seawall that may be successful in protecting a beach. However, the seawall may experience pressures from land failure (landslides and slumping) and consequently be destroyed from the flank or from the rear. The structure fails because groundwater seepage problems were ignored. Similarly, a well-drained slope may fail if the toe remains unprotected. What is needed to prevent structural failure is a comprehensive approach taking into consideration all aspects of shore processes.

Problems frequently encountered during and after installation of an erosion control device include:

(1) Improper Planning.

Often a property owner makes the wrong decision regarding the method or methods of protection. As stated above, a combination of erosion control structures may be indicated.

(2) Inadequate Construction Methods.

Lack of experience, carelessness or a misjudgment of forces may result in poor construction. Such structures have been found to fail in a short period of time.

(3) Improper Maintenance and Repair.

As in the case of any man-made structure, frequent maintenance and periodic repair is critical to the overall survival of the structure and to the continuing success of the design.

In addition, the lack of performance of many structures is due to the lack of information about the best available technology. A critical part of the coastal zone management efforts must be to continue to bring the most current information to the shore owner and the perspective builder of erosion control structures. The design of effective controls is dependent on on-going research and tests of a variety of designs. The owner and contractor must be willing to abandon traditional designs that have been shown to give only mediocre results.

Conclusion

It can be argued that coastal stabilization is futile in the long run. Shorelines are naturally subject to large-scale recessions and advances through time. Hence, seawalls and nourishment projects, etc., are at best, only temporary solutions (Mitchell, 1975). The protection of a particular piece of property within the context of an eroding shoreline is difficult, costly, and may prove to be ineffective.

The most effective and economical means of protection is achieved through coordinated action under a comprehensive plan which considers the erosion processes over a long period of time and over the full length of the receding shore (A Plan for Michigan's Shorelands).

The ten to twenty-five year frequency storm is capable of destroying shore protection projects and the property they were designed to protect. Construction of a major protective device capable of withstanding such a storm is generally beyond the economic means of the majority of shore owners.

It is important to realize that past practices have evolved no single "best" design resistant to failure. When it is realized that a tremendous percentage, probably well over 80%, of the money spent by private or public property owners on protection has provided ineffectual protection, it is obvious that it is very important to investigate additional designs and assess the causes of failure more closely.

The most effective methods of shore protection are designed to slow the process of erosion. This can be done by attenuating the erosive wave or preventing destructional waves from impacting the shore directly. To be even moderately successful, such structures must have an adequate foundation and be designed to prevent incremental failure by flanking or undercutting. In addition, the structure must be secure from landward influences.

The following section describes the types and methodology of a variety of designs available. It is emphasized that the successful application of any design is predicated on a thorough examination of the site and a careful application of engineering principles.

TYPES OF STRUCTURAL AND NON-STRUCTURAL TECHNIQUES

All of the various types of structural alternatives can be reduced to four main types. They are:

(1) Structures designed and intended to establish and hold a line that limits the lakes encroachment are called rigid sea defense lines. This category included seawalls, bulkheads, and revetments.

(2) Structures designed to capture or retain sand in compartments. The principal example of this category is the groin structure.

(3) Structures designed to attenuate wave energy. The primary purpose is to reduce the energy delivered to the beach face. Within this category are breakwaters of various design and jetties.

(4) Shore and beach stabilization techniques which closely approximate the natural processes. Examples in this category are beach restoration projects, beach nourishment projects, and the use of vegetation to stabilize beaches and bluffs.

In addition, there are several non-structural alternatives available. By definition non-structural alternatives are things done to regulate the activities of man in coastal areas (Parker, 1980). There are two main non-structural categories. They are:

(1) Those non-structural techniques that are considered within the institutional framework of local or state government. The category includes structural setbacks, zoning ordinances, storm water management, insurance programs, and acquisition.

(2) Those non-structural techniques that are considered the perogative of the individual property owner. Included in this category are relocation and site planning. Vegetation management, dewatering techniques, and runoff control are considered proper site planning alternatives.

The choice between structural and non-structural approaches involves a given level of risk (Parker, 1980). The structural alternative imparts a certain confidence that the threat is being met "head-on" and positive results are expected immediately. The non-structural technique recognizes the limitations of structures and considers the long term advantages of co-existence with the natural processes.

So little effort has been directed toward adopting the numerous non-structural alternatives that it is difficult to judge whether erosion costs would be reduced more significantly by investing additional money in techniques or broadening the range of adjustments to include presently neglected options such as land use controls, insurance, erosion forecasts, etc. (Mitchell, 1975).

Trends in Structural Alternative Application

During the 1930's and the 1940's seawalls and bulkheads were the favored techniques used against the forces of erosion. These structures are very much in evidence in areas of the coast where development took place preceding that time, particularly on the Atlantic Coast, but on the Great Lakes as well.

During the 1950's the trend, headed by the Corps of Engineers, was with beach nourishment projects. Research at that time demonstrated the positive nature of sand accumulation as a buffer against erosion. As supplies of sand dwindled and the costs related to moving it around increased, the trend moved to sand by-passing systems.

The late 1960's to the present has seen the trend move toward (1) land use management techniques, and (2) the design and installation of lower cost structures. The section will concentrate on seawalls, bulkheads, revetments, groins and beach nourishment as structural solutions, with passing comment on jetties and breakwaters. As mentioned previously, these structures are outside the financial capabilities of most property owners. Each of the types of shore protection has its own inherent advantages, disadvantages, and limitations for a variety of applications.

I. Structures Designed and Intended to Establish and Hold a Line That Limits the Sea's Encroachment

Revetments, Bulkheads, Seawalls

General Introduction

Generally, revetments, bulkheads, and seawalls can be defined as follows:

(1) Revetment - A revetment is the lightest of the three in terms of construction. It is designed to protect a shoreline against erosion by currents or light wave action. It is most often constructed with respect to existing or prepared slopes.

(2) Bulkheads - Next largest in size, they function to retain fill placed behind the finished structure. Ideally they are not subject to severe wave action on the open coast.

(3) Seawalls - Seawalls are the most massive of the three. They are well engineered, complicated structures designed to resist the full force of the waves (Shore Protection Manual).

The above definitions should be used in referencing these structures. Some confusion exists about the difference between seawalls and bulkheads but the above definitions clearly separate them according to mass and application as shore protection devices.

The three, however, have some things in common. They function to separate land and water by the placement of a physical barrier. They are used where it is necessary to maintain the shore in an advanced position relative to that of the adjacent shoreline. They are used when no naturally occurring beach serves as protection for the shore and, finally, they are used where it is necessary to maintain a depth of water adjacent to the structure as in the case of mooring facilities.

The general advantages of these structures are as follows:

(1) They provide positive protection allowing more intensive use of the adjacent shoreline.

(2) They maintain the shore in a fixed position, important in cases of shore development.

(3) They can be engineered to provide protection for an area without a severe incidental amount of damage to adjacent shore areas.

The general disadvantages include:

(1) They are not as effective in maintaining a beach.

(2) They provide no protection to adjacent areas which will continue to erode and ultimately expose the flanks of even the best engineered structure.

Revetments

Specifically, a revetment is a sloped facing built to protect existing land or newly created embankments against erosion by wave action and/or currents. They are constructed shore parallel and serve as armor for the face of the land. Construction materials vary but all serve to dissipate wave energy by allowing a degree of run-up as opposed to the vertical wall which confronts the wave energy more or less "head-on". There are three essential types based on construction methods and material used (Dradeau, 1978).

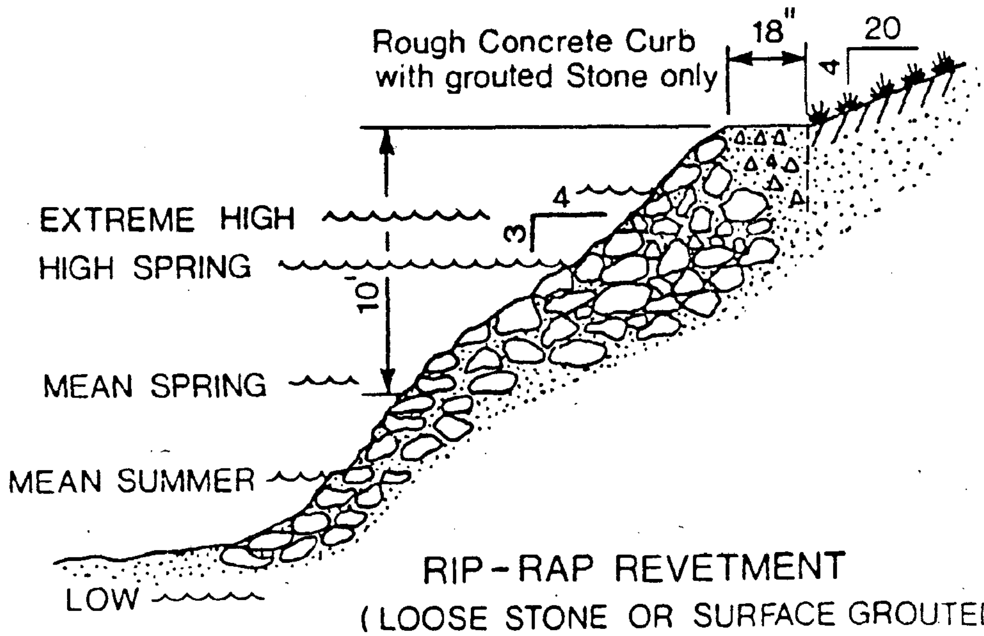
(1) Single Component Revetment (See Figures 9 and 10)

A single component revetment is composed by individual, unattached components placed directly on the bank or shore or over a filter material. Construction materials include stone rip-rap, concrete blocks, tetrapods, sacks (longard tubes), sand bags, automobile bodies, cellular blocks, or rubble. Occasionally some inspired applications of assorted debris is observed.

(2) Pavement Revetment

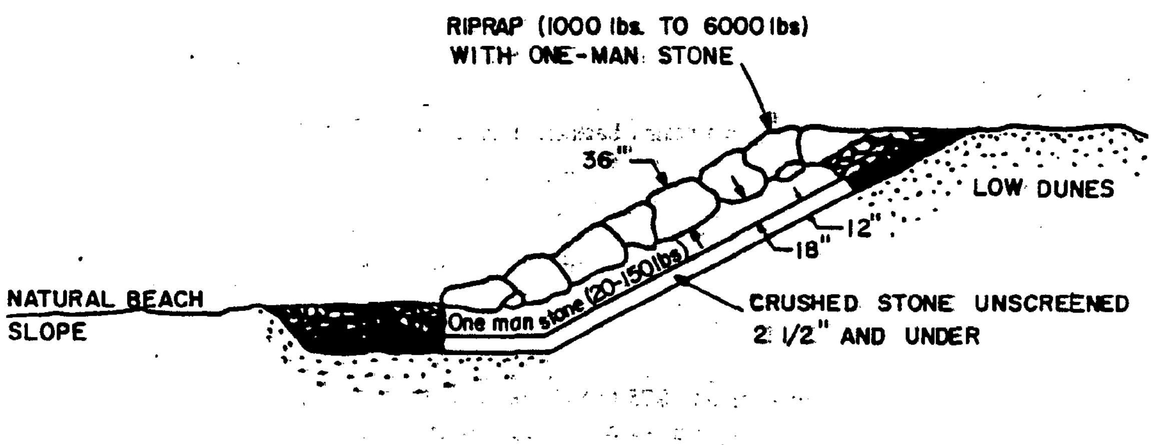
A pavement revetment is an impermeable application of concrete or asphalt over the slope serving as an armor plate against loss of material from the slope. It is used where applications of any of the above single component types is impractical.

(3) Mattress Revetment



RIP-RAP REVETMENT
(LOOSE STONE OR SURFACE GROUTED)

Typical Riprap Revetment



Mattress revetments are broad, flat applications of gabions or a network of attached concrete, wood, stone, etc. designed to be flexible allowing some movement while retaining structural integrity. They may range from articulated concrete mattresses to automobile tires strapped together.

Generally, revetments have been found to be successful. For example, a U.S. Army Corps of Engineers study found that "the most suitable, least cost structure for protecting that lake's (Ontario) U.S. shore is a revetment" (Staats, 1981).

Revetments are sometimes placed at the toe of the bluff to prevent scour due to wave attack. To be effective, revetments need toe protection, provisions for drainage, and must be built high enough so that most storm waves will not overtop them. Revetments may be highly effective if properly constructed, although they require maintenance to restore materials used in construction (Michigan Seagrant).

As mentioned above, they are not effective in maintaining a beach. Built back at the bluff toe and used in combination with a groin, for example, they may be part of a comprehensive program of shore protection.

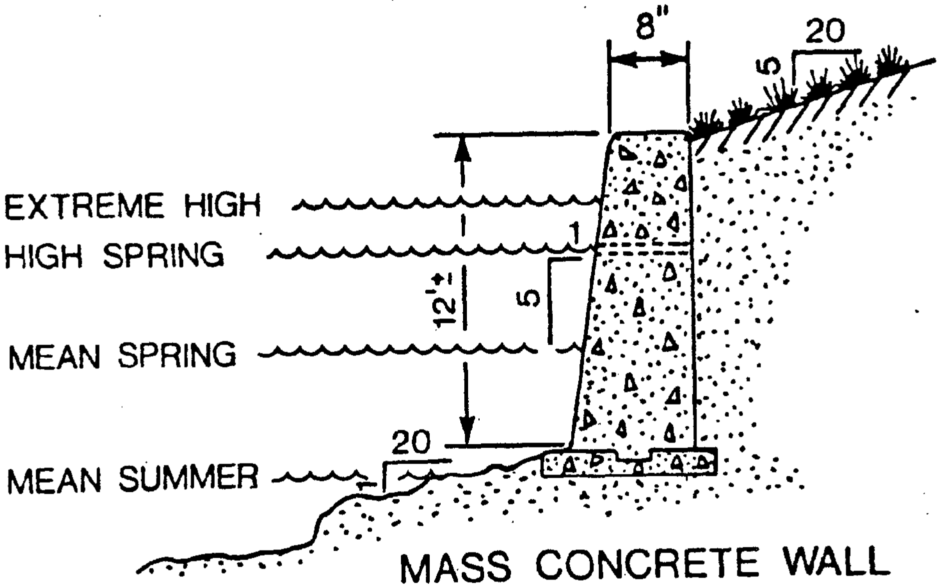
Bulkheads

A bulkhead is a structure or partition installed to prevent erosion of the land behind it. It is usually vertical or consists of vertical sections stepped back from the water and built parallel to the shore (Shanks, 1978).

Bulkheads are generally constructed of steel or timber interconnecting piles or of concrete. Some structures stand many years while many fail after the first storm. Obviously, the design and construction of the bulkhead must be able to withstand severe forces not only from the lakeside but from the land behind it as well. Failures in these structures result from excavation of the footing by wave action or as cracks develop as soil and water pressures build in the landward side. If they are to be a long term solution, provisions must be made to protect the footing by burying it deeply, tying into bedrock, or placing rip-rap in front to help absorb wave energy. A concrete apron behind assists in preventing washouts while drains relieve water pressure to a certain extent. Since its chief function is to hold back land, it should only be used in protected waters. (See Fig. 11&12)

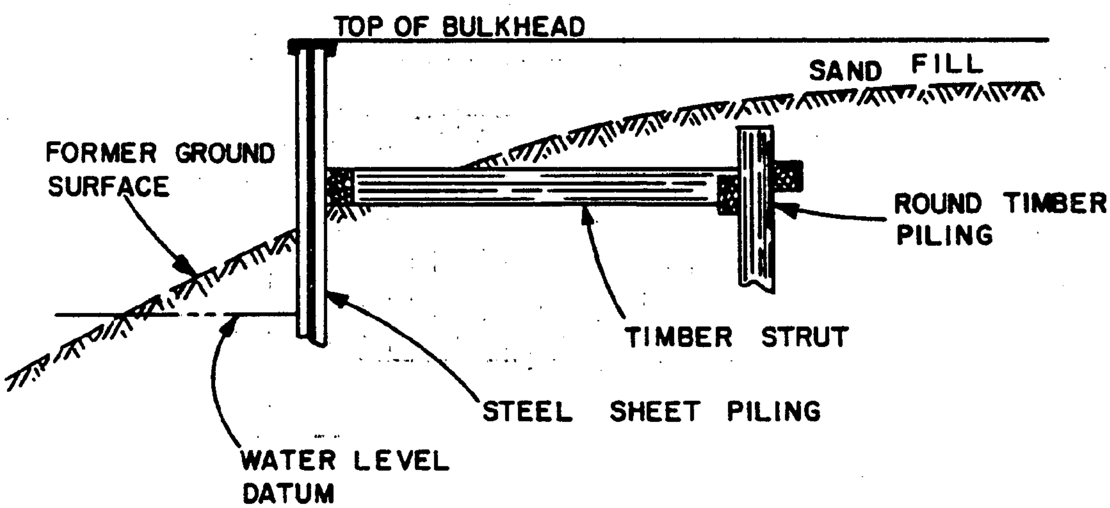
Seawalls

A seawall is a structure separating land and water areas. It is primarily designed to prevent damage to an upland area while retaining its seaward limit in a fixed position (Corps of Engineers, 1972). Seawalls are massive in design to withstand the constant attack by waves. They must be able to maintain structural integrity over time to be considered cost



MASS CONCRETE WALL

Typical Steel Sheet Pile Bulkhead



effective. Structural failure in seawalls is common due to under design. Proper design elements include:

(1) A capability to withstand large wave forces,

(2) A foundation safe from undermining (a rule of thumb is two-thirds buried to one-third exposed),

(3) A height sufficient to prevent overtopping,

(4) A design which limits the effects of flanking, and

(5) A structure which is appropriate for the site. (See Fig. 13)

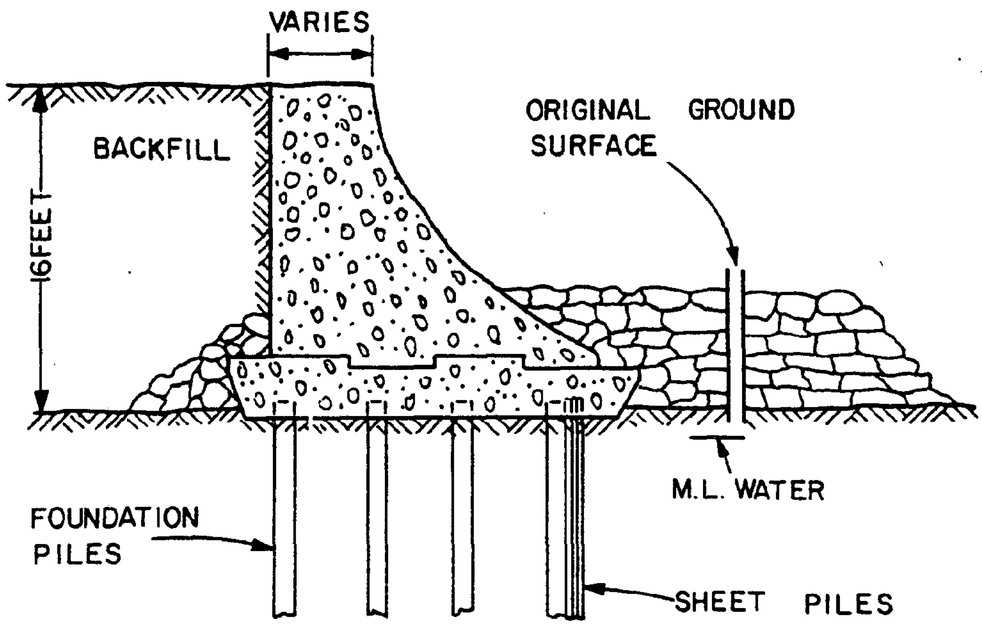
Seawalls fail for the following reasons:

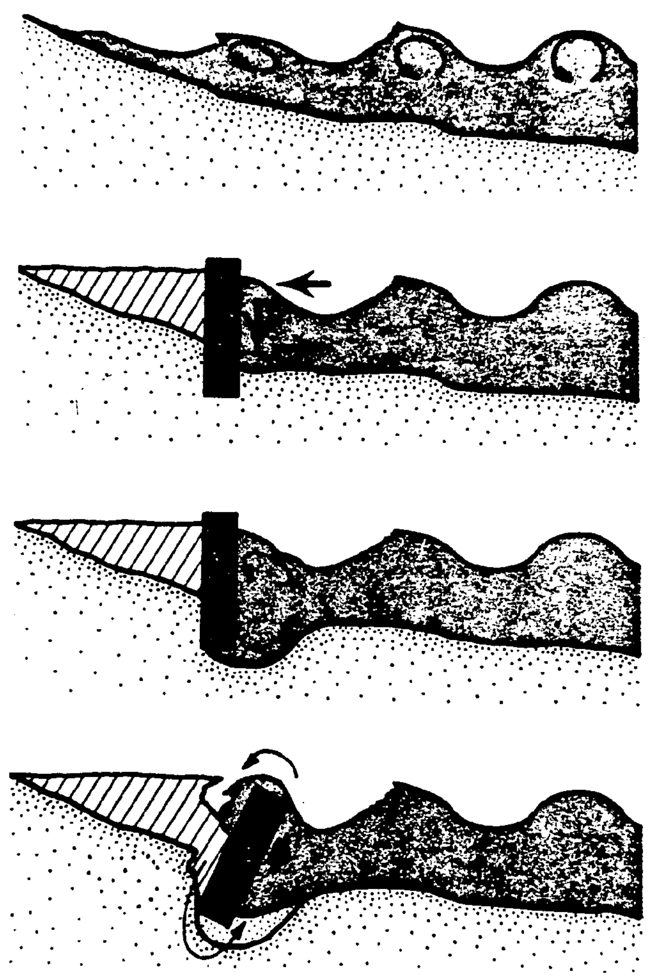
(1) Scour - The general design of most seawalls presents an obstacle to the on-rushing wave. The enormous energy of a large storm wave is driven downwards. If the seawall lacks protection at its base, continued scour will cause the structure to fail. (Figure 14)

(2) Omission of tie-backs - The structure must incorporate properly engineered tie-backs into the shore material. Lack of tie-backs makes the structure vulnerable to toppling as the soil and water pressures persist.

(3) Lack of return walls - Return walls protect the seawall from the flanking action that takes place as adjacent unprotected shorelines recede. As the structure is flanked by wave action and structural integrity is lost, the consequence is toppling. As mentioned above, the bulk of the structure should be below the lake bottom by two-thirds of its mass. This allows for the natural cycle of sand movement to take place without endangering the structure.

Typical Concrete Curved — Face Seawall





The greatest disadvantages of the seawall are the erosional losses of beach material and the difficulty of recreational access. Some designs, however, largely eliminate this problem. The normal seawall is vertical but large successes are reported from convex, concave, sloped, or stepped faces.

A convex or sloping design is the least effective in stopping overtopping but are well designed to solve the problem of scour at the base since the wave is allowed to "run up" dissipating its energy. The distinct advantage of this design is in application in protecting the toe of a bluff from wave erosion while minimizing scour induced erosion on the beach.

A concave structure is most effective against overtopping but increases the problem of scouring. As waves hit the curved face they are deflected back toward the water and downward. The wave energy is concentrated in front of the structure increasing the scouring action on bottom sediments.

A stepped wall reduces scouring while improving access to the beach. A stepped structure is more complicated and thus more expensive than a simple vertical or sloped structure. The distinct advantage of the stepped design is the surface texture. This texture reduces run-up and dissipates wave energy more than the smooth surface of the other designs.

II. Structures Designed to Capture or Retain Sand in Compartments

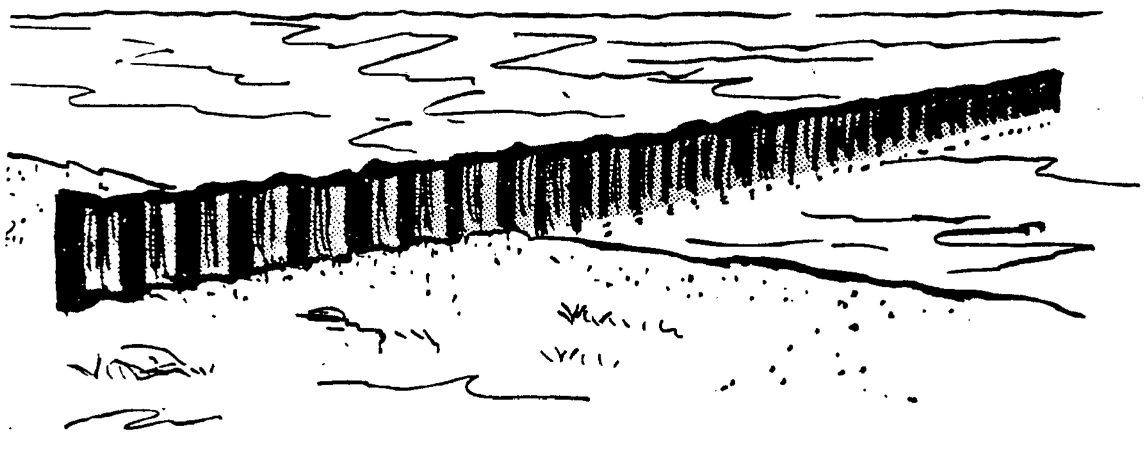
Groins

General Information

On the Erie County, Pennsylvania shoreline groins are by far the most common type of defensive structure. The reasons for this are not clear save for the fact that earlier groins achieved a moderate amount of success in general application. Despite their wide use in Erie County, as well as on other shores of the nation, the detailed operation of the groin is poorly understood. Failures can be traced to a lack of understanding of the functional design of groins and the littoral processes to which the structures are subjected (Shore Protection Manual). (Figure 15) (See also, Appendix II)

Groins or groin systems in many locations have achieved the intended purpose while in other areas only negligible benefits have resulted. Groins will do exactly what they are intended to do if they are appropriate to site problems and objectives (Parker, 1980). When properly placed in a series along the shoreline, groins have proven to be a most effective means of stabilizing a shoreline or creating beach where there was adequate longshore sediment transport.

Opinions vary on the benefits of groins as protective structures. The conditions for success vary with site and



design and the structural integrity of the completed structure. The purpose, conditions for use, and the advantages and disadvantages are discussed below. As in the case of all structures, prior to construction a complete knowledge and understanding of the natural processes is critical. Their functional success and their structural adequacy cannot be assured without a solid understanding of the natural forces and processes at work in the area (Parker, 1980).

A groin is defined as a shore protection structure built perpendicular to shore and designed to build a protective beach or to retard erosion of an existing or restored beach by trapping sediments in the littoral drift. Groins define compartments within which the longshore transport of sand is largely reduced.

The cost of constructing a groin varies widely and is dependent on location, size of structure, materials used in construction, and access to the shore zone. They are generally very expensive as an alternative for the individual property owner though, as mentioned, they are the preferred type in Erie County.

Two or more groins on a particular site would constitute a groin field. Research on the subject shows that the effectiveness of the fields is dependent on the relative value of each individual groin in the field. Generally, the costs, advantages, and disadvantages are magnified with additional structures while the benefits expected of multiple groins do not always occur proportionately. The purpose of a groin or a groin field can be stated as follows:

(1) To build or widen a beach by trapping littoral drift,

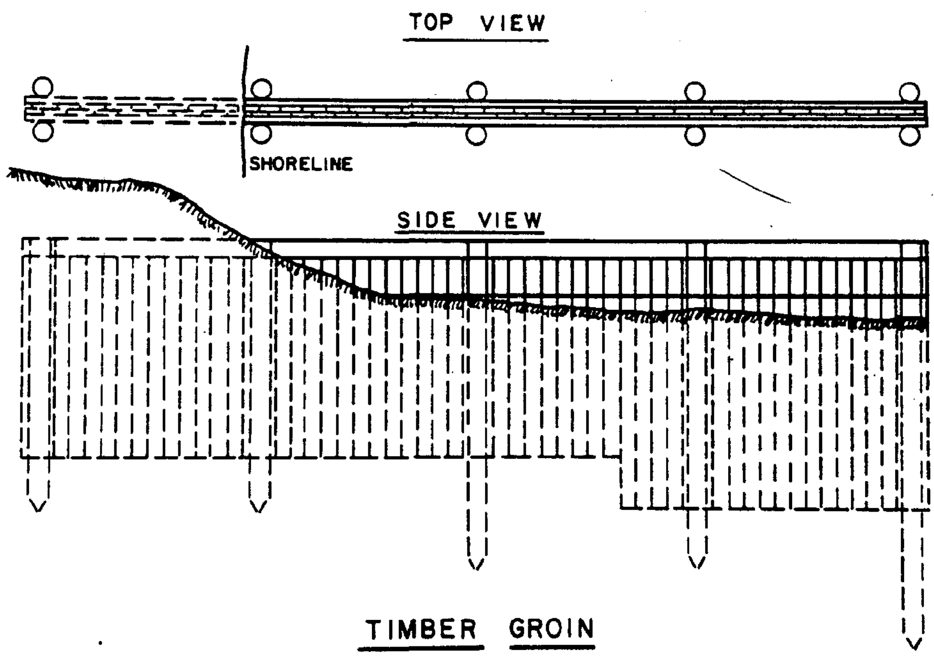
(2) To stabilize a beach subject to excessive storms or seasonal periods of advance and recession by reducing the rate of loss,

(3) To reduce rate of longshore transport out of an area by reorienting a section of the shoreline to an alignment more nearly perpendicular to the predominate wave direction,

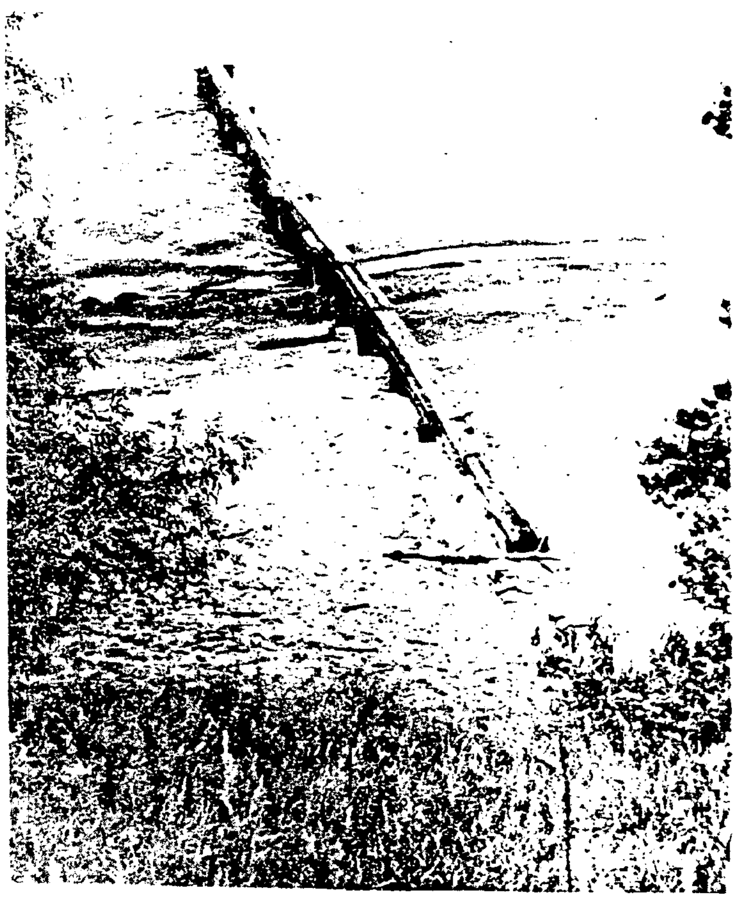
(4) To reduce losses of material out of an area by compartmenting the beach, usually a relatively short section of beach artificially filled seaward of adjacent shores, and

(5) To prevent accretion in a downdrift area by acting as a littoral barrier (Shore Protection Manual).

The typical construction materials for groins include timber, steel, concrete, or rock. Each provides its own unique advantages and disadvantages in site specific applications. Many structures have been built using a combination of materials. For example, a sheet pile structure may be given further structural integrity by the placement of rock on the updrift side to assist in breaking the force of storm waves. (See Figures 16 and 17)



TIMBER GROIN



Depending on wave climate, water level fluctuations, rate and direction of littoral drift, and, if associated with artificial beach nourishment, a groin or groin field may be:

(1) Effective as shoreline protection,

(2) Detrimental to the beach system by causing accelerated downdrift erosion,

(3) Ineffective for trapping sediment (Gutman, 1979).

A groin is effective only when one longshore direction prevails and there is a sufficient supply of materials in transport (Sanko, 1978) and ineffective where onshore-offshore movement prevails (Parker, 1980).

In addition, groins are ineffective when they are highly permeable and are both too short or too low. Scarcity of sand in the littoral is also a cause for ineffectiveness, lacking sufficient volume to build a protective beach. Artificial nourishment, discussed below, is an additional structural alternative which, when used in combination, can reduce the ineffectiveness due to insufficient materials in transport. In general, the advantages of groin construction can be listed as:

(1) The resultant beach provides protection to uplands as well as establishing a potential recreational site,

(2) Groin systems interfere less with the use of a beach than any other structure,

(3) Their effect may spread over considerable distance

of shore on the updrift side as sand accumulates, and

(4) At those locations where groins would be effective, protection can generally be provided at a lower initial cost than the other major shore protection works (breakwaters, seawalls, or revetments).

The disadvantages may be listed as:

(1) They are not as effective as a seawall for continuous upland protection,

(2) They may be out flanked as storm waves combine with high water levels removing more of the backshore area on the updrift side than the structure was designed to protect,

(3) They are ineffective in areas of low sediment transport,

(4) The area immediately downdrift of the groin may be subject to increased scour, and

(5) They may be ineffective as isolated units.

Conclusion

A groin or series of groins should be considered only after a careful analysis of the shore processes predominating on the site, including an evaluation of the direction of longshore drift and the volume of sand in transport. If there is insufficient sand and the additional expense of artificial nourishment cannot be borne, the concept should be abandoned as an alternative in favor of another structural alternative. Additionally, the impact of the groin on downdrift areas should be considered.

Overall, a groin design can function as intended if all conditions are met. As in the case of all structural alternatives, the benefits should exceed negative impacts to be at once cost effective and envirnomentally safe.

III. Structures Designed to Attenuate Wave Energy

Breakwaters

As stated previously, the breakwater concept is not suitable for individual protection of private property due mainly to the high cost of construction including a thorough engineering study. A discussion of breakwaters is provided mainly to acquaint the reader with their advantages and disadvantages and to introduce the floating tire breakwater as a moderate cost structural alternative in sheltered waters.

Breakwaters are seldom built solely for shore protection. The concept is used mainly to provide protection for navigation purposes. The size, of course, varies with the amount of harbor desired and the severity of the prevailing conditions.

Breakwaters are designed to reduce or eliminate wave action in their lee. A side effect and a response making them somewhat suitable as a shore protection device is the effect on littoral drift. The breakwater, when constructed fairly close to the shore, blocks the littoral drift by denying wave energy to the shore. This can cause accumulations of sand behind them as the energy needed to move material is largely eliminated. The classic example is the breakwater at Santa Monica, California and a local example can be seen at Budny Beach on Presque Isle State Park where a prototype rubble mound segmented breakwater system was completed in 1978. The structure at Presque Isle was built for the sole purpose of capturing sand in the longshore transport system. To this extent they have succeeded. However, the amount of downdrift erosion that has occurred since construction creates some doubt as to the overall benefits of the design concept. (See Figures 5 and 18)

By definition, the breakwater is installed parallel to the shoreline to attenuate wave energy to protect a shore area, harbor, anchorage, or basin to provide for the safe handling of boats and ships. They may be fixed (shore connected or detached) or floating in the case of the floating tire breakwater (FTB) design.

The advantages then, are primarily:

(1) To protect a beach area without impairing the usefulness of the beach, and

(2) To provide sheltered waters for navigation.

The disadvantages include:

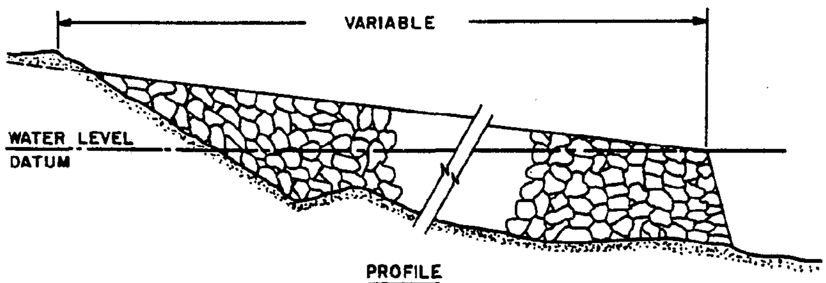
(1) A relatively high cost of construction,

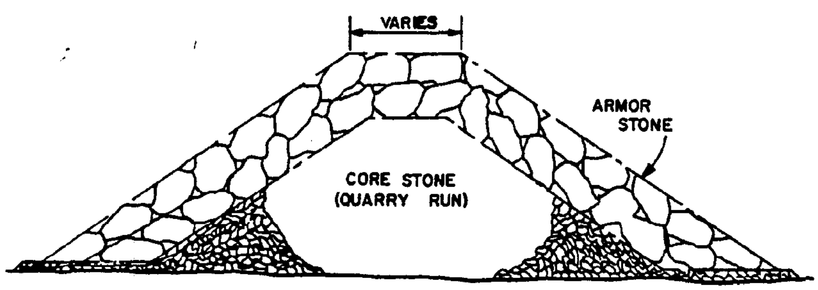
(2) A protection only of the shore behind them,

(3) An adverse effect on the downdrift area by removing sand from the transport system, and

(4) Because of the side effect of sand accumulation, the area behind a breakwater requires periodic dredging to remove unwanted sediment in navigation lanes.

Typical Rubble – Mound Groin





The Floating Tire Breakwater Design (FTB)

Research and experience have shown that FTB's are effective for improving coastal protection under specific wave conditions (DeYoung, 1978).

The advantages of the FTB are listed as:

(1) Construction costs are lower than those of conventional breakwaters, and large quantities of material are generally available. Their construction can be done by unskilled labor and light equipment.

(2) Effectively designed, a FTB can reduce wave height and prevent facility damage in the sheltered area behind the structure.

(3) Location and size can be modified to improve wave damping characteristics for a coastal zone.

(4) The FTB can be used in some regions where conventional bottom resting breakwaters are not feasible because of soft bottom, deep water, or sediment transport problems.

(5) They enhance biological resources in a localized area by providing an artificial reef for organisms.

(6) Their low profile in the water does not inhibit the scenic values of coastal areas.

(7) Currents are not impeded by a solid barrier. There are no stagnation problems common with conventional breakwater design.

(8) Compared with rock, wood, or metal breakwaters,

FTB's are of less physical hazard to boaters.

Their disadvantages include:

(1) Maintenance requires time and money not typically invested in conventional breakwaters.

(2) The breakwater cannot be moored year-round in coastal areas where ice is prevalent.

(3) The breakwater does not provide the degree of wave protection of conventional bottom resting structures.

(4) It can be a hazard to navigation and a source of liability if not properly marked.

(5) If the longshore transport is significant in a predominate direction, a FTB could produce negative downdrift impacts.

(6) The FTB can only be used in a sheltered area where waves do not exceed three feet with a long wave period.

The design is in a test and demonstration mode. The relative past success of the structure is an encouragement to researchers looking for the low-cost alternative to expensive shore protection schemes. It is offered here as an alternative to the rigid, bottom resting breakwater concept.

Jetties

A jetty is a structure extending into the water to direct and confine river flow into a channel and to prevent or reduce shoaling of the channel by littoral drift. It is typically employed at inlets in connection with navigation improvements.

Jetties and groins are similar in that they are both built parallel to shore and function to interrupt the littoral drift. The distinction is in the purpose of construction. The jetty is designed to prevent deposits in the lee of the structure while the groin is built to encourage deposits on the updrift side. Generally, the jetty is much larger than a typical groin. There is only one true jetty on the open coast of Erie County, located at the mouth of Walnut Creek. Constructed by the Pennsylvania Fish Commission, it is of rubblemound construction and designed to keep an open channel for the boat launch facilities in a man-made turning basin located 200 meters from the mouth of the stream.

Jetties are not constructed as shore protection works. They are mentioned here to prevent further confusion about terminology as applied to shore structures.

IV. Shore and Beach Stabilization Techniques Which Closely Approximate the Natural Processes

Beach Nourishment and Conservation of Natural Beaches

Beach restoration and nourishment is accepted as a structural alternative in erosion prevention since large quantities of sand are moved about using heavy equipment. The function of the natural beach was discussed at the beginning of this section. Beach restoration and nourishment projects are designed to approximate natural beach conditions. Because of high utility in dissipating wave energy, a properly maintained beach affords maximum protection for the adjoining backshore.

When conditions are suitable for artificial nourishment long reaches of shore may be protected by this method for a relatively low cost per foot of protected shore (Shore Protection Manual).

It should be noted that the cost is low compared to breakwaters or seawalls. Beach nourishment for the individual property owner can be expensive and unlikely to be maintained over time. Artificial nourishment is a "quick fix" solution to the major cause of most erosion problems--a deficiency in natural sand supply.

Beach nourishment is an increasingly preferred adjustment because it involves minimum interference with beach dynamics and can be accomplished with little ecological disruption and can quickly produce a usable and protective beach (NOAA, 1976).

Conservation of Sand

"Experience and study have demonstrated that sand from dunes, beaches, and nearshore areas is the best material available naturally in suitable form to protect shores" (Shore Protection Manual).

Inventories of submarine sand supplies and improvements in dredging technology have increased the prospect of continuous beach nourishment from offshore sources (NOAA, 1976).

If sand is generally available in quantity, protection of the shore is greatly simplified. However, large areas of coast no longer receive large amounts of sand by natural processes. It becomes apparent that sand, as a resource, must be conserved by preventing losses of sand offshore and by discouraging excess entrapment along the shore.

Beach nourishment projects offer distinct advantages:

(1) It is aesthetically pleasing as it preserves the beach in a natural condition.

(2) It benefits rather than damages the shore beyond the immediate problem area.

(3) It can provide immediate short-term protection.

There are some disadvantages. They include:

(1) The nourishment concept requires that beach nourishment be continued indefinitely.

(2) Supplies of sand reaching the downdrift shore can produce intermittent instability.

(3) Where littoral currents are active, the method can be impractical and expensive.

Beach nourishment, if carried out properly can be an effective means of shoreline erosion control. A commitment must be made to provide constant maintenance in a highly mobile beach environment. Where the littoral drift is less active the technique can be used in conjunction with a groin to maintain a beach without taking sand from the natural system.

The Protective Influence of Vegetation in Steep Slope Conditions

The bluffs along the Pennsylvania portion of the Lake Erie shoreline exhibit various rates of recession and erosion in response to varying conditions. The factors influencing these rates include:

(1) Undercutting of the bluff by wave attack accelerated by high water levels,

(2) The movement of groundwater between layers of permeable and impermeable layers,

(3) Runoff from shoreland area as sheet flow, from drainage ditches, septic tank outfalls, etc.,

(4) Sheet runoff on bluff surface,

(5) Soil creep,

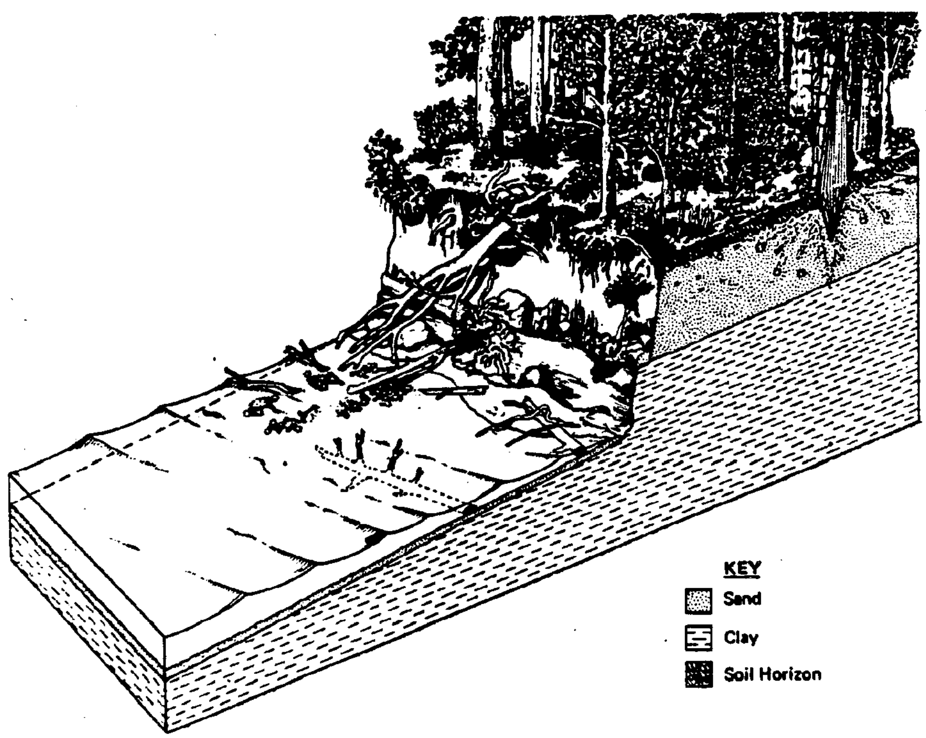
(6) Raindrop impact, and

(7) Frost action.

The role of vegetation in retarding the relative rates of erosion and/or recession is to delay the movement of water in the system. It should be noted that in the case of internal stress (slope failure), no amount of vegetation on the bluff face will prevent this falure. An example would be the movement of groundwater exiting as a spring line somewhere on the slope. The weakening is internal and slumping will occur carrying any vegetation with it. Another instance involves undercutting of the bluff by wave attack. The bluff becomes oversteep and slope failure occurs. Assuming no protection is planned for the base of the bluff, no amount of vegetation will prevent erosion. (See Figure 19)

The rate of groundwater flow can be slowed by a dense vegetative cover in the area behind the bluff crest. The plants act to retard the infiltration of water thereby minimizing the impact on the bluff face. Ideally, a strip of vegetation should remain as a buffer along the entire bluff line. If new plantings are to be made, it should be recognized that the bluff will recede and sufficient width be provided to guarantee maximum benefit through time.

In the case of three (3) through seven (7) above, each factor can be reduced as to impact by proper vegetative


KEY
Sand
Clay
Soil Horizon

management. In each case the vegetation acts to slow the movement of water.

The role of the vegetative root mat at theimmediate edge of the bluff should not be underestimated. On-site examination shows the retention qualities very well. It has been pointed out that often mature trees can produce a negative impact. As the root structure is undermined by movement on the bluff high winds can topple the tree taking several cubic yards of material with it. In such cases it would be wise to cut the tree before this can occur. If the species is of the variety that produces shoots from the main trunk the cutting can be made several feet from the ground in the hope that removal of the crown will prevent toppling while the roots remain alive to continue offering a measure of retention.

The recommendations made by the State of Michigan as to the role of vegetation and the various species considered important are as follows:

> Tree cutting and removal of other vegetative cover along the shores of the Corridor should be regulated to protect scenic beauty, control erosion, and reduce effluent and nutrient flow from the shoreland.
>
> Many plants, densely root and densely spaced, can aid in shore stabilization, particularly in noncritical erosion areas.
>
> Native, established vegetative cover should be maintained where it exists; additional plantings should be made to increase density where shown to be beneficial for purposes of either shore stabilization or scenic enhancement.

New cover should be established on exposed, erodible shorelands in conjunction with structural protection measures, or alone.

Plants considered important in terms of shore stabilization along the Great Lakes include:

Native Species

Pioneer Zone

Ammophila breviligulata	(beach grass)
Cakile endentula	(sea rocket)
Calamovilfa longifolia	(dune grass)
Ammophila breviligulata	(sand reedgrass)

Scrub Zone

Prunus serotina	(black cherry)
Salix syrticola	(dune willow)
Corrus stolonifera	(red osier dogwood)
Juniperus horizontalis	(creeping juniper)

Forest Zone

Arctostaphylus uva ursi	(madrona)
Populus deltoides	(cottonwood)
Populus tremuloides	(quaking aspen)

Exotic Species

Pioneer Zone

Agropyron dasystachyum	(hairy wild wheat)
Agropyron species	(wild wheats)
Artemisia species	(wormwood)
Elymus arenarius	(sea lymegrass)
Pteridium species	(brachen fern)

Scrub Zone

Cystisus species	(brooms)
Eleagnus srgentata	
Erica species	(heaths)
Populus species	(aspens and poplars)
Pyrecantha species	(firethorns)
Rosa species	(roses)

Forest Zone

Prunus virginiana	(choke cherry)

The manner in which shore cover is maintained, removed, restored, or reinforced is also important in aesthetic terms. Thinning out of trees is preferred to clear-cutting. Clear-cutting or severe thinning should not be allowed on highly erodible soils and slopes.

Shore cover regulation should extend to a strip depth which reflects both the vegetative type and the resource priority status of the shoreline. A minimum depth of 50 feet* in conifer--dominant regions, and 100 feet* in deciduous dominant regions, should be maintained in General Use Districts to ensure sufficient screening of structures and accessories. In Conservation Districts, the minimum depth dimensions should be 150 and 300 feet respectively. [In "hardship" cases, property owners could be allowed exceptions on the condition that a state-approved or locally approved landscape plan be first accepted.]

Where done, clear-cutting should not extend to more than 30 percent of the length of the shore strip of any property frontage.

Cutting that is more extensive than the 30 percent limit should be executed only in accordance with an approved cutting plan that would ensure suitable screening of structures and accessories.

Natural shrubbery should be preserved as far as practicable, and where removed, replaced with other vegetation equally effective in preventing erosion and preserving natural beauty.

Tree seedlings and shrubs should be made available at a nominal cost to shoreland owners to encourage restoration or reinforcement of shore cover.

The planting of new trees and shrubs as screens should utilize species, planting patterns, and plant heights that are compatible with the structural images they are intended to disguise.

(A Plan for Michigan's Shorelands)

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*Greater widths may be necessary in stands of old, tall trees because of proneness to wind topping.

Summary of Key Points in Considering Vegetation (Clemons, GLBC)

(1) Shallow rooted grasses provide a favorable habitat for the establishment of deeper rooted shrubs and trees.

(2) Vegetation removes water from bluff areas through uptake and transpiration.

(3) Roots hold soil particles in place while deeper roots of woody vegetation prevent slipping of soil layers.

(4) Vegetation slows runoff and acts as a filter to catch sediment.

(5) Vegetation can improve the visual quality of a shoreline.

(6) Vegetation slows wind velocity and traps wind-blown sediment.

(7) Vegetation absorbs the energy of falling rain.

(8) Vegetation helps to maintain absorptive capacity of the soil.

(9) Vegetation can reduce frost penetration.

Vegetation will <u>not</u>:

(1) Stop erosion due to wave action, or

(2) Control deep-seated movements associated with bluff failure.

There are few, if any, proven and guaranteed vegetative shore protection techniques that can function independently.

Combining vegetation and structural alternatives to stabilize bluffs should definitely be encouraged.

The preceding information in this section has dealt with the major types of shore protection techniques. The following information deals with the types of materials being experimented with to implement traditional construction techniques. The following will be discussed:

(1) The use of fabrics as filter materials,

(2) Sandbags and longard tubes,

(3) Gabions, and

(4) Miscellaneous (rubblemounds, rock-mastic, concrete blocks, planter box revetment).

This section is intended to give examples of some new techniques and is not a review of all the ideas being suggested as shore protection devices.

Fabric

Apart from the use of fabrics as containment devices described under sandbags and longard tubes below, fabric has general utility when combined with other materials as a filtering device. A woven sheet of polypropylene yarn, for example, permits water, under pressure of wave action, to pass through but prevents fine particles of sediment from washing away. The applications include the following:

(1) Separation - used to create zoning of materials or

separation of materials by size;

(2) Reinforcement - slope stabilization, retaining wall construction, soil containment systems, and concrete reinforcement;

(3) Drainage - internal drainage in earthen dams, drainage behind retaining walls; and

(4) Erosion control and/or prevention (Welsh and Koerner, 1979).

Generally, the fabrics are woven nylon, polyester, polypropylene, polyamide, polyethelene, or combinations of the above. The resultant cloth is anywhere from 3-151 mils thick and are priced from $.15 per square foot.

Sandbags and Longard Tubes

A longard tube is constructed in layers. Essentially, a woven material is coated with a polyvinyl sheeting. The tubes are 42" to 69" in diameter and are available in varying lengths. Sand is pumped into the bag as a slurry with the sand being trapped at the other end by the use of a filter material. The result is a semi-rigid structure that can be used in a variety of shore erosion prevention applications. Some key points offered by Armstrong and Kureth (1979) are as follows:

(1) It is difficult to generalize on the applicability of a wide variety of potential sites.

(2) The use requires a substantial period of time over which the structure must be closely watched to gauge its performance and effectiveness.

(3) It appears to have enough favorable observation to now be defined as a concept that has moved from "unusual" to some respectability.

(4) The longard tube is definitely low cost (approximately $30 per foot of protection) with respect to more familiar concepts.

(5) The device has reasonable endurance. Vandalism (slashing the bag) seems to be a specific problem mentioned by many researchers.

(6) A structure of longard tubes can be constructed in a relatively short period of time.

(7) Placing of a longard tube is not a do-it-yourself project though it can be done easily by a contractor equipped for the job. (See Figure 20)

Three applications of the longard tube as part of the Shore Erosion Control Demonstration Project are described below.

In an experiment at Empire, Michigan some shifting of the bags was noted. Also, a single tube was unable to withstand wave forces.

At Lincoln Township, Michigan longard tubes were used to construct a groin at a cost of $57 per foot of protection.

Problems encountered included a lack of sufficient tie-in with the shore and some settlement. It was judged to be a good but temporary solution as it performed its basic function of accumulating sand behind it but was not expected to withstand wave forces beyond a two to three year period.

A revetment of longard tubes was built at a Moran, Michigan beach at a cost of $57 per foot of protection. Again, shifting of the tubes presented some problems although there was some positive effect in protecting the bluff.

Experimentation has shown (Brater, 1974; Gutman, 1979; Machemehl, 1977; Armstrong, 1976) that giant sandbags may be used with a measure of success. Similar to the longard tube, the bags measure 10' x 5' x 1.5' and hold 2.5 cubic yards of sand. Marketed under the name of "Durabag" and "Sand Pillow" they are being used for groins, low cost revetments, or as a supplement to traditional construction techniques. With an economic life of two years, they compare favorably with other, low cost techniques. For example, a sand bag groin can be built at a cost of approximately $40 per foot of protection and a revetment could cost as little as $12 per foot of protection. One method used was some creative stacking to help attenuate wave energy over an irregular surface. (See Figure 21)

Some problems encountered in placement include filling the bag, finding the right materials offsite and, as in the case of the longard tubes, vandalism.

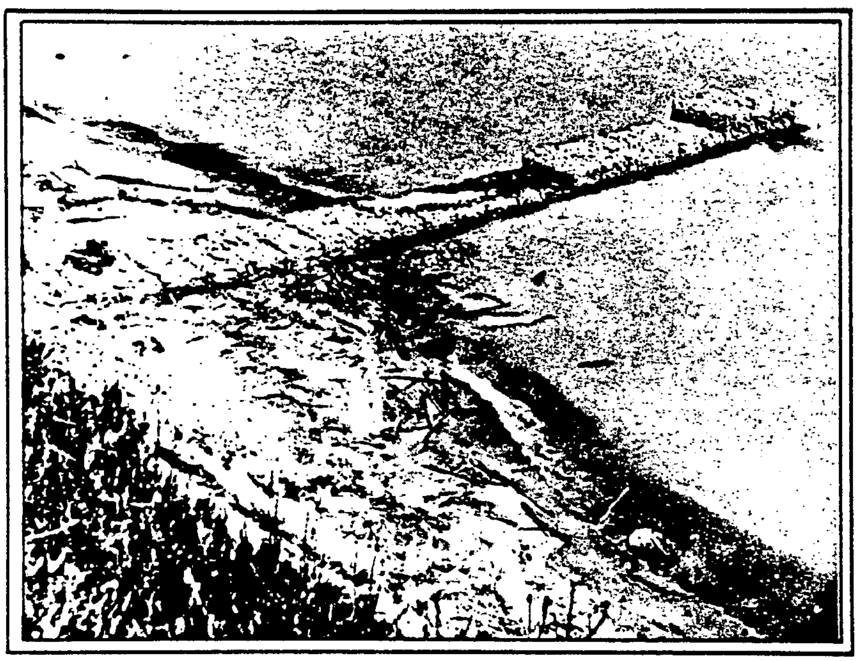
An experimental revetment was constructed at Moran, Michigan using sand bags. For some time after construction researchers claim it was working to protect the shore and the bluff behind it (Brater, 1974).

If the property protected is valuable, sandbags placed and maintained over two to three year periods could offer low cost protection to a shore with a mild wave climate.

Longard tubes, grout filled bags, and giant sandbags have been tested at Presque Isle State Park. As an experiment the configurations used failed to protect the eroding shores. Because of the severe wave climate the structures were easily overtopped and flanked. It is interesting to note, however, that many of the bags are essentially still in place with a minimum of shifting and/or settling.

Gabions (See Figure 23)

Gabions are wire mesh baskets approximately 3' x 1.5' x 1.5' in size holding up to five cubic yards of material. The material placed in them varies from natural stone to concrete rubble. As in the case with all such structures, the materials should not come from the shore to be protected but rather



Gabion groin, 3 miles south of Port Sanilac, MI.

from offsite landward locations. The baskets, in various arrangements can be used to construct groins and revetments. The advantages of gabions include:

(1) Property owners can construct them themselves if suitable materials for filling them can be found and delivered to the site.

(2) They are durable, yielding to some pressures but essentially maintaining shape and position.

(3) They are permeable, retaining sediment while allowing water to pass through.

(4) The coarse texture assists in attenuating wave energy.

Gabions can be an effective, low cost, temporary means of retarding shore erosion. Placed in front of existing structures (bulkheads, revetments, or groins) the gabion assists in attenuating wave forces and reinforcing the existing structure.

Miscellaneous Structures and Techniques

Rubblemound Structures and Rip Rap

Rubblemound structures have been increasingly used as a low cost alternative to more rigid structures. They are not used by individual property owners because of the difficulty and expense of handling large rock but have utility in major construction works such as breakwaters and large groin systems.

A large amount of engineering data are now available as a result of concentrated effort by researchers interested in their utility. However, major and costly failures in rubble mounds continue to occur (Edge, 1976). According to Edge (1976) the following are indicated:

(1) Structures built in deep water should question the traditional methods of design and construction.

(2) Use of large armor units indicate a need to reconsider criteria by which damage to structures is defined in model studies.

(3) Hydraulic model tests should also model actual strength of the individual armor units.

(4) Constant monitoring of the structure should determine early signs of structural failure.

Despite the fact that rubblemounds are not generally used by the individual property owner, the concept should be investigated by municipalities as an alternative given the cautions expressed above.

Rip rap rock revetments are seen with increasing frequency as a shore protection device. As with the rubblemound structures, the individual property owner cannot consider it due to the large size of the material used with the consequent cost. They are successful if carefully engineered with the stone size in keeping with the expected wave forces. Rip rap can be used in association with rigid structures as a first line of defense to reduce scouring at the base. In use the rip rap revetment should be constructed in keeping with the previous discussion on revetments.

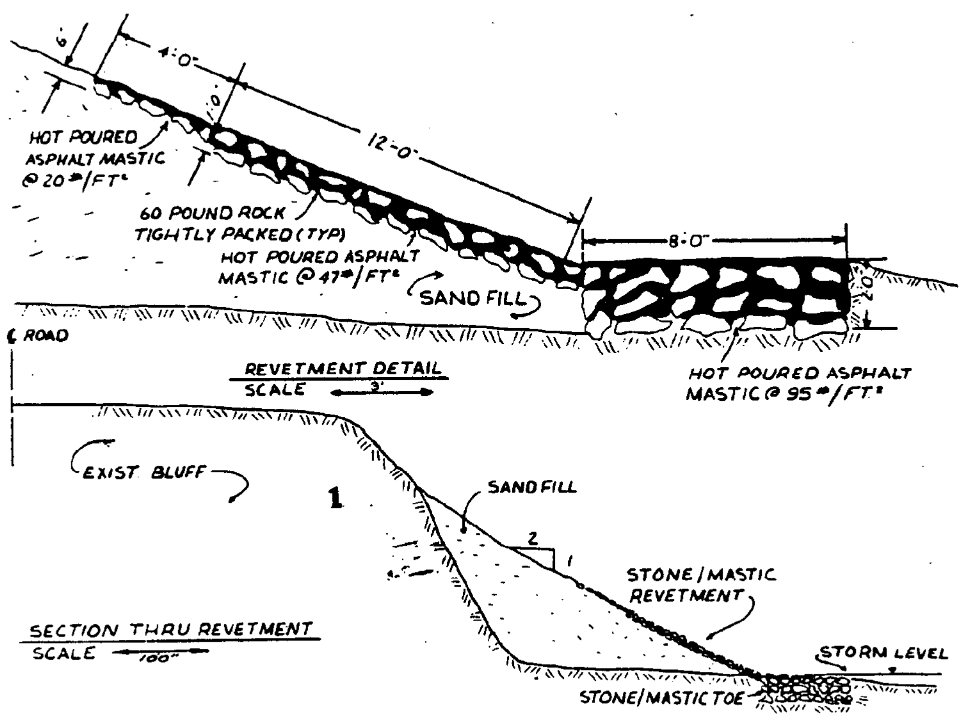
Rock Mastic Combinations (See Figure 24)

Typical structures employing this technique would include groins and revetments. Mounds of rock 6" to 12" in size are covered with asphalt as a paving material. They should only be used by experienced asphalt materials specialists with the heavy equipment needed for installation.

An experimental rock mastic revetment was constructed at Michigana, Michigan as part of the Erosion Control Demonstration Program. According to researchers (Brater, 1974) the structure performed well during the first year stopping erosion in that area and showing great promise as an erosion control device.

Planter Box Revetment

The planter box concept involves a steel reinforced, locally precast, site assembled massive concrete box. The technique is based on the principle of terracing. The boxes are placed on a 30-35% prepared slope and underlain by a filter fabric. The boxes are filled with soil and plant growth is encouraged. It would appear that the concept has some utility on a low wave climate shore.



6"
4'-0"
1'-0"
12'-0"
8'-0"
2'-0"
HOT POURED ASPHALT MASTIC @ 20#/FT²
60 POUND ROCK TIGHTLY PACKED (TYP)
HOT POURED ASPHALT MASTIC @ 47#/FT²
SAND FILL
HOT POURED ASPHALT MASTIC @ 95#/FT²
REVETMENT DETAIL
SCALE 3'
℄ ROAD
EXIST. BLUFF
SAND FILL
2
1
STONE/MASTIC REVETMENT
STORM LEVEL
STONE/MASTIC TOE
SECTION THRU REVETMENT
SCALE 100"

Concrete Building Blocks

A structure assembled from concrete blocks can be expected to collect sediment as part of their function. However, most configurations cannot be expected to protect a shore against any wave greater than one meter. They are easily overtopped by higher waves and are easily undermined by scour at the base. Advantages include:

(1) The materials are readily available at low cost.

(2) They can be handled easily by the individual property owner and can be installed without the need for skilled labor.

(3) The installation does not limit recreational access.

(4) In some cases, vegetation can be established on the revetment face (Giles, 1977).

Others

Other materials that have been experimented with include modifications of the traditional timber crib design, zig zag panels designed to interfere with wave energy, preformed concrete rings, dolos, etc. Structures built of such diverse materials have some utility and may function as designed in areas where a more traditional design may be successful but where economics dictate a lower cost alternative.

The above has been a general examination of many types of structural alternatives. Further information is available in a variety of sources and specifically in the U.S. Army, Corps of Engineers' publications Help Yourself and the Shore Protection Manual. These materials should be consulted for detailed descriptions and applications as well as engineering design "do's and don'ts".

Non-Structural Alternatives For Shore Erosion Protection

There are many alternatives to building a structure to reduce losses due to erosion. They should be given serious consideration before the expense of complicated shore structures is incurred. They include:

A. Institutional Arrangements
   1. Structural setbacks and zoning
   2. Stormwater management
   3. Insurance
   4. Acquisition
   5. Relocation

B. Private Arrangements
   1. Site Planning
      a. Vegetation Management
      b. De-watering
      c. Runoff control

Each of the above points will be covered illustrating the key concepts of each.

Institutional Arrangements: Structural setback requirements and Zoning

"Development of land on the top of the bluffs has resulted in acceleration of the natural erosion process. Development activities result in the removal of soil stabilizing vegetation, alteration of the surface drainage patterns, and increased impacts from runoff and wave action" (OSPD, 1978).

"To protect banks and bluffs and minimize hazards, (the) community will need to enforce setbacks and controls on such factors as water seepage and physical alteration" (Conservation Foundation, 1980).

Development should be set back from the unstable bluff areas so that an erosion prone zone adjacent to the bluffs is maintained free of development. Structures should not be allowed to diminish the scenic quality of the bluffs, and public access to the bluff areas should be assured. Vegetation at the bluff edges should be maintained, and land disturbing activities should be discouraged (OSPD, 1978).

Crowding of the water's edge and improper construction, a frequent cause of excessive property damage, can be controlled by the establishment of set back lines and building code restrictions (Environment Canada, 1973).

Through the Coastal Zone Management Program, Pennsylvania has successfully passed enabling legislation providing for the establishment, at the municipal level, of a Bluff Recession and Setback Act. As a result, the local governments involved have created zoning ordinances which establish a recession line with a prohibition on construction lakeward of the line.

These ordinances have been established after preliminary studies revealed the extent of the hazard (Knuth, 1974). Any ordinance of this nature, to be successful, must be based on scientific evidence of its necessity and should be imposed only after proven.

A community may assure that future development is set back--not just from the present edge, but ideally from an anticipated future edge (Conservation Foundation, 1980).

Establishing a setback presents four principal problems:

(1) To calculate a setback requires extensive data collection.

(2) There may be a need to re-evaluate setback distances as changing physical phenomena dictate.

(3) What is the optimum time over which erosion can be expected to cause bluffs to recede. Should it be 50 years?

(4) What should be done about non-conforming buildings and unbuildable lots?

The municipal ordinances in Erie County cover these key points. In particular, variances are provided for certain conditions. It should be stressed, however, that liberally granting variances may render the ordinance ineffective. Not present in the majority of the ordinances are provisions for protecting the bluff face.

Specifically, the ordinances should be expanded to:

(1) Discourage activities that physically alter the face or toe of banks and bluffs.

(2) Prohibit removal of vegetation and excavation that increase the chance of bluff failure.

(3) Prevent removal of rubble or debris from the toe area. Such removal fosters increased erosion of the base.

(4) Prohibit structures of any type on the bluff face.

Proper setback ordinances have two distinct advantages:

(1) If the area is kept in a natural or semi-natural condition, slope stability is fostered, and

(2) Proper maintenance of the bluff and proper setbacks landward will reduce the need for structural measures at the bluff toe.

In addition to bluff recession, there is the continued problem of shore erosion. There is no provision in the Bluff Recession and Setback Act for ordinances covering the area between the bluff crest and lakeward of the toe of the bluff.

Such an ordinance could be established at the municipal level and should provide for the following elements:

(1) Locate all structures away from the beach slope area. If there is insufficient space between the beach backshore and the toe of the bluff, construction should be prohibited.

(2) Avoid removing sand from parts of the beach system, including the shallow nearshore zone.

(3) Maintain natural beach processes by discouraging structures that adversely affect littoral drift (Conservation Foundation, 1980).

Non-Structural Alternatives: Insurance

Up-to-date information related to insurance programs covering losses due to erosion in the Great Lakes comes from the Great Lakes Basin Commission's position paper on the Coastal Hazards Element of the comprehensive plan (GLBC, 1980). "Amendment of the erosion hazard insurance provisions (Sections 1302(g) and 1370(c) of the National Insurance Act of 1968, as amended, is needed in order to eliminate the insurmountable technical and administrative problems that have resulted since 1973 from attempts to implement an insurance program for coastal erosion."

And further:

"FEMA should promulgate specific standards for payment of erosion related claims, and make the strongest possible effort to insure that notice and complete understanding of these standards reach all involved parties."

Non-Structural Alternatives: Acquisition, Relocation

The literature is mixed with regards to relocation as witnessed by the following.

Due to the prohibitive costs and significant political and social disruption, acquisition of entire coastal hazard areas is not feasible as a major means of coastal hazard mitigation (McKinney, 1980).

While according to NOAA (1976), "in many places, either acquisition or relocation can be a preferred alternative to structural protection," and,

"Directed abandonment or relocation of established uses is beyond the realm of social and economic reality" (Jones, 1978).

Clearly, removing an endangered structure, with consequent government acquisition, is a proven method. However, an examination of the financial costs involved place the concept beyond the means of most municipalities who, usually, have their hands full protecting what they already have in the shore zone in the way of public lands and/or structures.

Non-Structure Alternatives: Private Arrangements

A companion report will deal extensively with the issue of stormwater management and the role of groundwater in causing erosion and recessional losses and will not be dealt with here. A publication of the Great Lakes Basin Commission, The Role of Vegetation in Shoreline Management, discusses that issue extensively.

Work Element 4.b.

THE CAUSE AND EFFECT RELATIONSHIP BETWEEN EROSION CONTROL STRUCTURES AND SUBSEQUENT DOWNDRIFT EROSION

General Introduction

This section should properly deal with the impact of shore structures on physical forces at work in the beach zone. The literature strongly suggests the cause and effect phenomena between the two. The following is a summary of current thought as well as an investigation into the kinds of side effects that can be expected. In some cases the position taken is strong. "In spite of mounting evidence that we are dead wrong, we persist in the practice of putting rigid barriers in the way of natural forces. We insist on occupying land that needs to move to survive" (Speight, 1975).

Others suggest that proper planning and design can mitigate the impact but no serious researcher denies that the construction of any barrier will produce a negative effect somewhere in the system.

The shoreline of Erie County, Pennsylvania is undergoing development, largely in the conversion of farmland to residential use. This changing land use has brought the homeowner into direct conflict with the natural forces. Land that has, historically, been developed is now facing increased threats due to persistent high lake levels. The solution is generally an attempt to reduce the threat by placing barriers on the shore. These attempts to stabilize a particular site usually compounds the problem offsite. We are learning that these devices are, in the long run, destructive of the very features we mean to preserve. (See Appendix II)

Researchers generally agree that the shore is a dynamic system undergoing constant cycles of erosion and accretion. It is also agreed that natural beaches are the best defense against loss of property. During the erosion phase of the cycle the placement of any structure will destroy the flexibility of beaches to respond to changing conditions. "There is inadequate information to assess the coastal system as an integrated system of sediment erosion, transportation and deposition operating over an extended period of time" (McGill, 1980). "The problem of shoreline damage due to littoral barriers is now widely recognized and must be considered in the planning of all coastal structures (Roellig, 1978).

The key to understanding the cause and effect relationship between erosion and subsequent impact is in understanding the nature of the longshore transport system. Longshore transport is dependent on wave climate, beach profile, shoreline configuration, sediment budget, currents, offshore bathymetry, and existing shoreline structures with waves as the primary driving force (Noble, 1978).

The Pennsylvania Coastal Zone Management Program, through extended research, is attempting to look at some of these parameters and will, as a result, be in a better position to make recommendations concerning the placement of shore structures. Essentially, we now know that sand, or the lack of it, is of prime importance. Any sand taken from natural processes is a loss to downdrift users and erosion of those beaches follows (Parker, 1980). Although there are many examples of man's intervention in coastal processes....man's critical modification of the balance of sediment and depletion of the supply of sand to the beaches of the world has reached a critical state (Inman, 1978). This is as true for Lake Erie as it is for the Atlantic or Pacific shores.

The historic development of barriers (usually groins) in the Erie County Coastal Zone has significantly reduced the amount of sand available and has created a redistribution of sediment to the benefit of the builder and to the detriment of others. Any structure placed in the water will have some effect, however minimal, on the wave and current patterns with which it interacts (Kureth, 1980). Structures such as groins, built perpendicular to the shoreline into the surf zone will obstruct the longshore current resulting in the deposition of sediments on the updrift side of the structure (Terich, 1975). Any artificial structure that produces a local accretion of sand by interrupting the transfer along the coast will cause a corresponding local erosion just downcoast from the area of accretion (Inman, 1980).

Impacts will vary with the type and size of the structure built. Simison et al (1978) offers five parameters for evaluating the impact of structures.

(1) The length of the structure relative to its offshore distance,

(2) The incident wave length relative to the offshore distance of the structure,

(3) The depth of water at the shoreward face of the structure,

(4) The incident wave vector of wave approach at the structure and the resultant wave shadow in the lee of the structure, and

(5) The position of the structure relative to the active littoral zone.

Unfortunately, the usual structure is placed bearing on a variety of factors having little relationship with the above. Generally a structure is evaluated by the property owner based on a perception of the success of a similar structure nearby or is promoted because the nearby structure is having a negative effect on his property. In this case the problem is merely being passed off to the next downdrift owner.

The following section is a discussion of the specific types of structures commonly built and the direct and indirect impact on the total reach.

Groins

"It is well known that groins constructed on coast stretches with a longshore material transport cause a reduction or cutoff of the transport in the beach zone (Mikkelsen, 1977).

"By far, the most dramatic coastal interference occurs when man interrupts the longshore transport of sand by the construction of....groins" (Inman, 1978).

Groins by design are intended to entrap sand moving in a shore parallel direction. The rationale is that such sand will act as a buffer causing waves to lose energy as run-up. Storm waves will, of course, serve to remove the accumulated sand in an offshore direction. The sand lost off shore will in turn be replaced by the longshore transport system. By design, most groins function exactly as intended. The problem, as stated above and re-stated by any number of researchers is that the sand entrapped is prevented from reaching the downdrift beach. The result is a starved sediment budget downdrift with consequent erosion.

The extent of the downdrift erosion depends on the efficiency of the groin or groin system in trapping sand and the amount lost offshore as the sand passes around the end of the groin (Everts, 1979). Both of the above serve to reduce the volume of sand reaching the downdrift beaches.

Everts (1979) makes a very valuable comparison between a shore without groins and one with groins. The comparison is as follows:

Coast without groins:

(1) Sediment transport along a coast is a combination of onshore or offshore and longshore movements.

(2) If a net longshore transport of sediment exists, this movement is probably occurring in a complex zig zag pattern with a downcoast component.

(3) Net losses from, or gains to, the beach from the offshore region are usually small in comparison to the net longshore transport rate past a point on the beach.

(4) Shore parallel movement occurs on the foreshore, in the surf zone, at the wave breakpoint and on the existing longshore bars.

Coast with groins:

(1) For sand to pass by a groin system in a shore parallel direction, it must move seaward of the groin ends.

(2) The sand moves about of mid-point axis that is further from shore, in deeper water, less on longshore bars.

(3) The consequences of this seaward deflection of the littoral zone will likely be a decrease in the transport rate and an increase in offshore deposition rate off the groin system.

In other words, the groin forces the river of sand offshore where some is lost to the deep and is thus unavailable to the shore downdrift.

The following should be kept in mind by those proposing construction as well as by planners and permitting agencies:

(1) Groins which capture all littoral drift should not be constructed since they aggravate or encourage beach erosion.

(2) Downdrift beaches will recede until the groins are filled and sand by-passing occurs.

(3) A series of groins will take longer to fill prolonging the period during which downdrift shorelines are exposed to erosive forces (Shanks, 1978).

(4) If it can be determined that problems created by construction outweigh any expected benefit they should not be permitted.

(5) Property owners on the downdrift side are usually forced also to construct groins lest they lose their beach (Terich, 1978).

(6) Even with an adequate supply of sand in the system, downdrift beaches may erode while the updrift side is filling.

(7) Updrift sides of groins should be artificially filled and artificially maintained to reduce amount of lost, naturally occurring sand.

(8) Some erosion downdrift will always occur (Sanko, 19).

In summary, groins serve to redistribute sand in the system by trapping it on the updrift side thus diminishing the amount downdrift. One property owner with a structure will create a chain reaction whereby downdrift property owners will be forced to construct protection measures, usually another groin. Unfortunately, there is not enough sand in the system to fill them all and the majority do not function as designed. A starved groin is generally lost to scour, flanking, or breaching.

Groins should be discouraged as a structural alternative unless artificially filled and maintained.

Bulkheads, Seawalls, Revetments

Key Points:

(1) The presence of a seawall, bulkhead, or revetment on a shore often promotes erosion of the foreshore in front of the structure caused by waves reflecting off the face of the structure (Shanks, 1978).

(2) When built on a receding shoreline, the recession will continue and may be accelerated on the adjacent shores promoting flanking (Shore Protection Manual).

(3) Attempts to reduce erosion by maintaining a static shoreline by the construction of shore parallel structures such as seawalls, bulkheads or revetments has resulted in losses and damage to the beach systems and related resources (McKiney et al, 1980).

(4) During storms, seawalls prevent landward erosion of the natural beach profile. Typically, the natural profile of the sections of beach without seawalls will erode during storm conditions and establish a submarine bar offshore which, in turn, provides protection by tripping the higher waves and preventing them from reaching the beach (Walton, 1979).

(5) Any downdrift impacts related to the construction of bulkheads, seawalls, and revetments comes from the fact that the shoreline is now protected and is not contributing sediment to the longshore transport system (Sanko, 19).

Breakwaters

Key Points:

(1) A solid breakwater can decrease circulation, interfere with waves and currents, and obstruct littoral drift (Shanks, 1978).

(2) In the absence of wave action to move sand, it is deposited lakeward toward the breakwater. The consequent build-up serves as a barrier which also blocks the movement of littoral materials producing an "end of groin field phenomena" starving the downdrift beach. The segmented breakwaters at Presque Isle State Park are a classic example of this negative impact.

(3) Detached breakwaters produce only minimal impact when the offshore distance of the structure is greater than

six times the breakwater length (Simison et al, 1978; Noble, 1978; Inman and Frautschy, 1965).

Jetties

Key Points:

(1) Nearshore currents can be disrupted; erosion and accretion can occur locally in patterns far different than pre-existing patterns.

(2) Jetties at stream mouths alter the rate of both river outfall and interfere with the littoral current (Shanks, 1978).

(3) Sand is impounded at the updrift side of the jetty and the supply of sand to the shore downdrift from the inlet is reduced, thus causing erosion of that shore. The Pennsylvania Fish Commission jetty at Walnut Creek is a classic case of producing cause and effect.

Conclusion

It is apparent that any structural methodology designed to reduce shore erosion will produce some negative effect or impact. In a design analysis of a shore improvement project provisions should be made to mitigate, to the extent possible, any adverse impact.

For example, groin induced damage can be mitigated by: (1) making groins permeable; the optimum design for permeable groins would allow a sufficient amount of sediment into the downdrift reach while continuing to provide protection, or (2) by artificial beach nourishment at the time of construction and as a continuing maintenance item.

Artificial nourishment is also useful to establish a feeder beach to introduce sediment into the longshore drift as a means of establishing beaches in front of bulkheads, seawalls, or revetments and removing the threat of downshore erosion as the result of construction.

Effects on adjacent lands should be considered to the extent of providing the required protection with the least amount of disturbance to currents and future land use, environmental factors, and aesthetics of the shore (Shore Protection Manual).

Conflicts between human activities and physical shoreline processes cannot be easily resolved resulting in:

(1) Some coastal areas have become hazard zones where the risk of destruction by wave induced activity or flooding is high, and

(2) Areas have become artificially protected reducing the risk of destruction but often altering the natural coastal system causing extreme physical impact elsewhere in that system (McGill, 1980).

Work Element 4.c.

DESIGN CRITERIA THAT MUST BE MET TO PROVIDE AT LEAST A MEASURE OF SUCCESS FOR EROSION CONTROL STRUCTURES

"Poorly conceived and improperly designed protection projects function poorly at best" (Parker, 1980).

Before an approach can be rationally selected, the problem must be identified and described, its cause determined, and an objective established.

(1) Why is the shoreline retreating?

(2) Is sand being lost to longshore transport or offshore?

(3) Are losses due to updrift structures?

(4) Are such losses temporary or continuing?

(5) What is the value of property and/or structures to be protected?

(6) Should wave energy be opposed or absorbed? (Parker, 1980).

These are the question that should be properly answered as a first step in the planning process. Most can be answered by observing a particular site over a brief time. Making a wrong decision at this stage will act to diminish the success possibilities of the alternative chosen.

The next step is to involve a qualified engineer to reduce the risk of failure by designing protection for the conditions at a specific problem area. The design of shore protection works is complex and good engineering principles must be followed.

An individual contract may or may not have engineering expertise at his disposal. Most contractors design their own structures and have little knowledge of forces or processes involved along the shoreline.

The second phase in planning should consider the following categories of information:

- Function
- Site Characteristics
- Engineering and Economic Factors
- Construction Material
- Expected Life Span
- Physical Impacts
- Review of Structural and Non-Structural Alternatives

1. Function

The function of the erosion control structure should be clearly defined. The builder has a definite goal in sight, whether it is the intent to trap sand or to oppose wave forces, there is an express result in mind. This result should clearly be compatible with the type of structure proposed. The design of the structure should be in keeping with the desired function. Over design will have direct bearing on the offsite impact which must be kept at a minimum. The design must be just enough to affect protection.

If the express intent is for recreational beach, boat launch facilities, or other non-protective use, the builder should be discouraged from continuing through the planning process.

2. Site Characteristics

The plan should contain a detailed sketch of the physical location. Included in the sketch should be the following:

(1) Width of beach,

(2) Beach profile (to a depth of 2 m),

(3) Nature of beach materials (fine sand, coarse sand, gravel, cobbles, etc.)

(4) Condition and configuration of bluff, and

(5) Orientation from north.

In addition, some consideration should be given the following:

(1) Hydraulic Considerations

a. Wind-predominate direction and force

b. Waves-to include the wave climate parameters of height, period and storm frequency

c. Currents

d. Offshore bathymetry (presence of bars, etc.)

(2) Sedimentation Considerations

a. Type of sediment in transport

b. Rate of transport

c. Predominate longshore drift direction

d. Sediment budget

The above data are relatively easy to gather for an individual site. Part of the coastal zone management education function should be a brochure outlining the methodology for site data collection. With this information as part of the plan, some intelligent decisions can be made relative to the suitability of a particular design.

3. Geographic Prevalence

What is the nature and extent of other shore protection structures in the area? Are they functioning as intended? What is the probable impact of adding an additional structure?

4. Engineering and Economic Factors

Information on specific engineering design criteria follow this section. In addition, the booklet, <u>Help Yourself</u> (U.S. Army, Corps of Engineers) details the types of engineering information and procedures that should be considered.

The cost of the structure should be carefully weighed against the most probable results. It has been found that the cost of some structures far exceeds the value of the property that would otherwise be lost during the expected lifespan of the proposed structure.

The types of structures affordable by most property owners are definitely in the low cost category. Care should be taken to ensure that low cost structures once built will be properly maintained. Property owners should be held responsible for clearing failed structures if they present a navigation hazard or an aesthetic impact. The property owner should be told the probable lifespan of the proposed structure to avoid false expectations and financial disappointments.

5. Construction Materials

Inadvisable solutions for erosion problems include debris dumped on bluffs, sewer pipes used as bulkheads, small sandbag revetments, tires on poles, or randomly placed large concrete blocks, small stone revetments, and low cost seawalls. Poor methods usually offer no effective protection, are unsightly, and may result in greater shoreline problems (Michigan Seagrant).

Care should be taken to prevent "mining" of existing beach for building material. Such removal or redistribution will adversely affect natural physical processes and possibly create more problems than their use as structural components may solve.

6. Expected Life Span

No low cost structures will escape some damage from the 25-50 year frequency storm. As mentioned previously, the life span of most low cost structures is 2-3 years and amount to temporary solutions that require constant maintenance and repair.

Generally speaking, emergency protection may provide a reasonable degree of protection through the first storm with the degree of protection diminishing as additional storms occur. Cost is a factor. It is estimated that the annual cost of maintenance of emergency protection could well be twice the initial construction costs (Corps of Engineers, 1972).

7. Physical Impact

Care should be taken in the development of a shoreline so as not to aggravate the erosion process. Moreover, it is imperative that each property owner realize the potential consequences of his actions on adjacent properties as he seeks to alleviate the erosion of his own land (Terich, 1975).

A full examination of cause and effect relationships is offered in Section **2** of this report.

8. Review of Structural and Non-Structural Alternatives

The property owner should properly complete the planning process by carefully reviewing his alternatives to ensure the proposal is the best possible choice and that the structure proposed answers the basic questions posed above. Then, and only then, should he be encouraged to enter the permit seeking phase of construction.

The construction of new shore protection structures such as jetties, groins, seawalls, bulkheads, or revetments can be conditionally accepted in the permitting process if they meet the following specifications:

(1) The structure is essential to protect water-dependent facilities or heavily used public recreational beach areas from erosion or to protect existing structures and infrastructure in developed shorefront areas from erosion.

(2) The structure is designed to eliminate or mitigate adverse impacts on the local shoreline sand supply.

(3) The structure will not create net adverse shoreline sand movement conditions downdrift, including erosion and shoaling.

(4) The structure will cause minimum adverse impact to living marine resources (McKinney, 1980).

Conversely:

(1) Sound compliance innovations will receive proper considerations rather than automatic rejection.

(2) Every justifiable criterion will be considered.

(3) Imposed standards will be no more rigorous than necessary.

(4) Requirements unnecessary for specific situations will not be imposed arbitrarily (Jones, 1978).

Each criterion should be thoroughly evaluated and modified as necessary to be certain that it is consistent with risk concepts proper for long term public purposes, long term public shoreline needs, and potentially critical environmental protection needs (Jones, 1978).

Groins

Key Points:

(1) Two points expressed in the published literature seem to be in agreement: (a) there is no standard or stock groin design, and (b) the best groin spacing (for groin fields) is somewhere between two and four times the groin length (Berg and Watts, 1971).

(2) Because of its limitations, a groin should be used only after a careful consideration of the many factors involved.

(3) Groin length is a function of water depth or a function of the distance from the shoreline to the average breaking point of plunging waves.

(4) It is suggested that groin length is a function of the distance from the shoreline to the first inner bar.

(5) A permeable groin could cause the required deposition yet allow a significant amount of littoral drift to pass through to alleviate some end of groin field effect.

(6) The interests of sound coastal management demand that the benefits of groin construction, repair and removal be carefully analyzed when and where possible (Wang et al, 1979).

(7) A high groin, extending through the breaking zone for ordinary or moderate storm waves initially entraps nearly all of the alongshore moving sand.

(8) Low groins (no higher than desired beach dimensional high point) allows some sand to pass over the top.

(9) Groin dimensions depend on the wave forces to be withstood, type of groin, and the construction material used.

(10) The length, profile, and spacing of groins in a system, direction of wave approach, and the rate of longshore transport are important functional considerations.

(11) Since most of the littoral drift moves in the zone landward of the normal breaker zone, extending a groin lakeward of that depth is generally uneconomical (Shore Protection Manual).

(12) The design of a groin system should consider the worst possible event.

(13) If conditions are not right or if the groin is improperly designed, the erosion problem that prompted the groin may not be solved (Sanko, 19).

Seawalls, Bulkheads, Revetments

Key Points:

(1) It has been recommended that shore parallel structures such as bulkheads, seawalls and revetments in areas characterized by sandy beaches, be prohibited.

(2) Such structures impede the natural migration and storm responses of sandy shores and result in significant increased losses of natural beach areas (McKinney, 1980).

(3) The major considerations for structures of this type are foundation conditions, exposure to wave attack, availability of materials and cost.

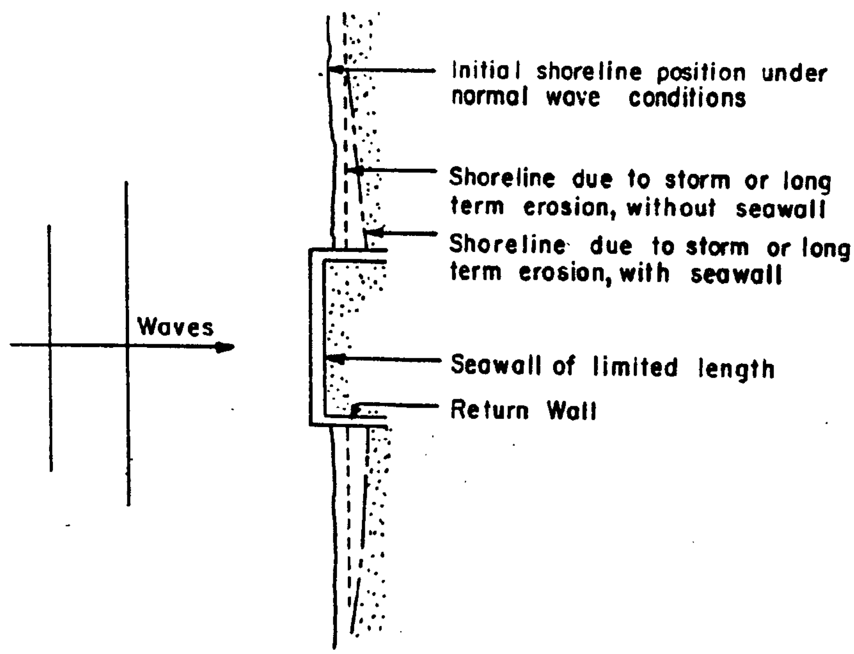
(4) Other factors in planning and design are the depth of wall penetration to prevent undermining, tie-backs or end walls to prevent flanking, stability against saturated soil pressures, and the possibility of soil slumping under the wall. (See Figure 25)

(5) Concave curved or reentrant faced structures are the most effective for reducing wave overtopping.

(6) Factors to be considered in design include (a) use and overall shape of the structure, (b) location with respect to the shoreline, (c) length and height, (d) stability of soil landward, and (e) lake level.

(7) Usually erosion may be expected at both ends of a structure; wing walls or tie-ins must be provided to prevent flanking and possible progressive failure of the structure at the ends.

(8) Scour may be anticipated at the toe of the structure as an initial short term effect. A rubblemound structure may


Initial shoreline position under normal wave conditions
Shoreline due to storm or long term erosion, without seawall
Shoreline due to storm or long term erosion, with seawall
Waves
Seawall of limited length
Return Wall

PLAN VIEW

sink due to scour.

(9) As a general rule, the maximum depth of a scour trough below the natural bed is about equal to the height of the maximum unbroken wave that can be supported by the original depth of water at the toe of the structure.

(10) The placement of a rock blanket with an adequate bedding material lakeward from the toe will prevent erosion at the toe resulting in a more stable structure.

(11) Buttresses can be added to bulkheads and seawalls to provide additional support.

(12) Small groins are sometimes used in conjunction with bulkheads and seawalls to help collect protective sand.

(13) A seawall is generally warranted only if reducing wave overtopping is urgent. Examples might include road protection, high density development, etc.

(14) The importance of any specific design used must take into account the consequences of seawall failure as well as the initial cost of the seawall. In the past, seawall design has been governed by the amount of money the upland owner has been willing to spend (Walton, 1979).

(15) A cooperative approach of neighboring properties should be promoted for greater protective strength and the elimination of flanking.

Artificial Nourishment, Protective Beaches

Key Points:

(1) Determination of the predominant direction of longshore transport and deficiency of material supply in the problem area are important considerations.

(2) Determination of the composite average characteristics of the existing beach materials or native sand in the zone between the 30 foot depth and the bluff face should be a priority.

(3) Evaluation and selection of borrow material for initial beach fill and periodic nourishment, including the determination of any extra amount of borrow material required for placement based on the comparison of the native beach sand and borrow material is critical.

(4) In addition, the following should be determined: (a) beach berm elevation and width, (b) wave adjusted foreshore slopes, and (c) feeder beach location (Shore Protection Manual).

SECTION THREE: MODEL EROSION CONTROL PLAN

CONTENTS

INTRODUCTION

"...Natural systems are dynamic; the survival of an organism or an environment depends on its ability to change in and around it. This knowledge has a way of burying itself when we lay out a property line and a piece of earth becomes real estate" (Speight, 1980).

Land use has been based on the concept that once land is used for a particular purpose that change ceases and attempts at change should be met head on. If we maintain a value for land it is in the best interests of the occupant to maintain stability as well and consider any natural change as undesirable.

It must be accepted that erosion and coastal flooding along the shores of Lake Erie are naturally occurring events and that these events pose a hazard to the coastal zone occupant. Attempts to reduce or eliminate erosion often produce negative impact. A component of the eroded material is the sand-sized particle that serves to protect the beaches and bluff wherever it accumulates. To prevent erosion of this material is to deny some protection elsewhere in the system.

Essentially problems in beach morphology are caused by human actions. If nothing is built on the beach, there is no "damage" if the beach changes shape. A beach will remain in various shapes as long as the process of natural replenishment continues. It may shift with the seasons, yield sand temporarily to storm erosion, slowly recede landward with rising water levels or accrete seaward with natural shifts in the flow of currents. Mobile and responsive, the beach will remain over the years (Conservation Foundation, 1980).

The main threat to any beach area and the bluff behind the beach is development. To "freeze" this natural area in space and time requires structural controls. Such controls require management and thus present the case for erosion control ordinances. When shore property is threatened by erosion of beach or bluff, the first reaction is generally to contrive a structural remedy. Such activity must be regulated.

Wherever there is a discussion of the desirability of public regulation of private land use as a means of coping with the hazard of extreme events, a specific statement should be made of the probable effects of permitting continued development of that area. The majority of the problems with coastal erosion are the direct result of ignoring shore development in the past (NOAA, 1976). A single response by a property owner to abate shore erosion can produce a chain reaction of events as outlined in Section **2**

There are three subjects that bear upon shoreline development (Jones, 1978). They are:

- Natural hazards
- The rights of the general public to develop shore areas, and
- Restrictions and/or regulations concerning development from the federal or state perspective.

What is needed for effective management is a strategy whereby local authority can control construction of shore protection works, the issuance of permits for structures, the removal of sand and gravel from the beach foreshore and any changes in the use of bluff slope, as well as continued administration of the bluff set-back ordinance.

Two basic problems confront the coastal planner; (1) how best to regulate land on which existing occupance is threatened with damage, and (2) how to regulate unoccupied land in hazard zones for which permission to construct is sought. The sample ordinance developed here should, if adopted, provide the municipality with regulatory authority to manage construction of works in four zones:

- Beach Foreshore
- Beach Backshore
- Bluff Slope
- Bluff Crest and Landward to the Recession Line

BASIC ASSUMPTIONS

The following are basic assumptions that can be made relative to hazard response by the community:

(1) Shorelines are a dynamic system, seldom at equilibrium, and subject to great changes in morphology in response to environmental conditions prevailing at any particular time. The full impact of these changes is, at times, difficult to perceive by casual observation. Only when forces combine to produce a catastrophic event do people become alarmed. The most serious events tend to be periodic and at random places along the shoreline.

Occupance of the coastal zone considers the 99% of the time when erosion is not accelerated. The lack of planning for the 1% event has caused great concern and produced various responses that are altogether too little and too late. A major function of the planning ordinance should be to alert the innocent or uninformed prospective occupant to the 1% probability event.

(2) Natural changes are increasingly predictable and quantifiable. Recent research activity sponsored in part by the coastal zone management program has provided government with technical data related to cause and effect responses in the shore zone. As more dollars are channeled into research, the obvious beneficiaries are the property owners. As

awareness of physical processes increases, the public has been less likely to spend large sums of money on shoreline development in hazard areas. The warnings that researchers provide will have a positive impact on mitigating future loss potential.

(3) Natural changes are potentially endangering to property. Each new permitted shoreline occupancy or exploitation action, though incremental and seemingly negligible in its significance to the community, cumulatively increases degradation of environmental quality in addition to property or structure loss (Jones, 1978). Consideration of hazards implies an added incentive for protection of the remaining undeveloped shoreline.

The Coastal Zone Management Program has given responsibility to the municipality to maintain the shoreline in a safe and healthful condition. In addition, the municipality should protect against costly shore erosion, control building sites, control placement of structures, and regulate land use. It should also act to preserve shore cover and natural beauty. This responsibility has been recognized generally with respect to:

(a) Public Health

Development pressures on the coastal fringe create a demand for additional services not now existing. Specifically, the placement of leach fields and septic tanks in highly permeable sand layers adversely impacts water quality in higher density development areas.

(b) General Welfare

The increased use of shoreland areas effectively removes the opportunity for non-shoreland property owners to access the coastal fringe.

(4) Potential endangerment is likely to imply public costs that will vary according to the scale of the disruption. A threat related to high density development is the likely pollution rising from improperly treated sewage. This generally involves great public expenditure by all levels of government to install and maintain proper sewer and storm water systems.

In addition, government must consider the loss of revenue due to decrease in value of properties having appreciable losses from erosion. A property owner seeking tax relief from this decreased value can generally convince the courts that such tax relief is indicated (Kerns and Scheid, 1980). Despite the fact that increased development will increase the tax base, expenditures for public works, sewers, culverts, controlled drainage, etc., far exceed the amount collected. Additional expenditures for solutions to the erosion problem are often requested by the property owner.

Erosion losses of beach and bluff significantly decrease both the amount and value of shorefront property. As shore erosion and bluff recession continue over time, the municipality may expect a lower tax return while still faced with the problem of providing essential services.

(5) Governments should avoid or minimize costs in keeping with the mandate to promote health, safety, and general welfare.

(6) Governments may avoid or minimize public costs by prohibiting or regulating development within known endangered areas. Rather than planning for site specific problems, regulations should be comprehensive, considering erosion processes over the full length of the municipal shoreline. Such an approach is more efficient and cost-effective. Regulating the shore by ordinance and imparting accumulated knowledge can increase understanding and respect for the natural shoreline processes. This can minimize future damage.

"It can be forcefully argued that the strategy which would yield the greatest long-term benefit to all of the people....would be a total cessation of development in shoreland areas. Further development will diminish the quality of the shorelands; with no further development, the integrity of the natural shoreland ecosystem can be considered to the maximum degree" (A Plan for Michigan's Shorelands, 1973).

A regulatory policy is not likely to meet with popular approval where restrictions on property or on structures to protect property combine with natural processes to diminish value. Nor would they meet with acceptance where a particular reach is undergoing real estate growth. The regulations would have maximum effect in promoting sound practices in areas of new development or in undeveloped areas.

While citizens may desire increased federal or state funding for protection, they rarely welcome its side effect--increased public access to "their" beach as a result of governmental projects facilitating such access. Nor are they likely to endorse strict regulations over what can and what cannot be done on their property. A possible answer to this dilemma is discussed in Section I.

MANAGEMENT ALTERNATIVES

From a review of pertinent literature two courses of action dominate in attempting to mitigate erosion and flooding:

(1) Engineering Techniques

(2) Management Techniques

The first seeks to meet the forces of nature head on with works designed to keep the impact of natural events from adversely affecting occupance of lands in the shore areas. Such works should be regulated by the local governing authority to ensure proper design.

The second is an attempt to control development in the coastal zone to remove as much threat as possible to structures and appurtenances.

Engineering techniques are designed to influence the physical interface of land and water while management techniques are intended to influence people in their use and development of the shorelands (A Plan for Michigan's Shorelands, 1973).

The enactment of land use controls to mitigate erosion hazards is a post W.W. II phenomena stemming from disenchantment with traditional structural protection practices and also from a growing need to resolve coastal conflicts (NOAA, 1976).

The adjustments to coastal erosion follow one of the following:

(1) Adjustments to loss, including loss-bearing and insurance programs,

(2) Modification of loss potential including coastal zoning, building codes, acquisition, and relocation, and

(3) Modification of erosion hazard through groins, bulkheads, revetments, seawalls, beach nourishment, and breakwaters (White, 1976).

Number one above is clearly a poor choice for most people who have large sums invested in shore property. Number two includes those adjustments generally considered as non-structural while three utilizes the structural alternative.

The major issues in dealing with the above include:

(1) How to provide least expensive, most effective and most acceptable protection.

(2) How to avoid conflicts with property owners.

(3) How to finance structural alternative if cost has to be borne by government.

(4) How to resolve the public access and ownership question.

(5) How to resolve disagreements about environmental impact (Mitchell, 1975).

Adoption of a specific response to erosion can increase, decrease, or have no effect on the likelihood of other adjustments being adopted. For example, if erosion control and protection structures are adopted, it is likely that they will be complimented by warning systems and relief and rehabilitation programs. It is less likely that non-structural controls and land use management tools will be employed (NOAA, 1976). A mix of alternatives promises to be the most effective program. An example might be an ordinance for hazard occupance coupled with beach nourishment or other structural alternative.

Land regulation of coastal hazards and sensitive areas can provide a long term mechanism for effective mitigation of erosion losses. Such regulations should be put into effect immediately to prevent additional losses and a continuance of poor land management. Regulations enacted now will do little to prevent short-term losses to existing development in hazard areas.

The currently available information shows that control of development along the coast, in many instances, may be the best practical way of reducing shoreline damage (Environment Canada, 1973).

Regulation should not arbitrarily impose obstacles to proper occupancy. It should require sound occupancy standards and should allocate shoreline areas to uses that will be in harmony with both the environmental and anticipated human needs.

LAND USE CONTROLS

There are generally three responses to erosion hazard. They are:

- Modification of the loss potential
- Modification of the erosion hazard
- Acceptance of unavoidable loss

The following are examples of management alternatives that generally modify the potential for loss:

- Density credits
- Compensable set-backs
- Set-backs
- Planned unit development
- Acquisition
- Permits
- Moritoria on building construction
- Building codes
- Scenic easements
- Transfer of development rights
- Erosion and sediment control laws
- Subdivision review process
- Zoning

The following are examples of strategies that generally modify the erosion hazard:

- Beach sand protection laws

- Grading and slope ordinances
- Drainage and sanitation codes
- Standards for seawalls, revetments, bulkheads and groins
- Regulations on tree cutting
- Regulations on filling, dredging and grading

The following are those alternatives that can generally be considered for bearing the unavoidable loss by erosion:

- Flood insurance
- Relocation

It should be pointed out that not all of the above will likely be adopted by any municipal ordinance or group of ordinances. It is anticipated that a mix of the above will be utilized to achieve the desired results for the municipality. In fact, some of the above may already exist in municipal ordinances. The above strategies are offered as a means of dealing with particular problems related to specific sites.

REQUIRED INFORMATION

It should be apparent that to successfully construct, administer, or enforce an erosion control ordinance, a considerable amount of information must be in hand. To preserve the qualities of the coastal zone through proper planning, government must undertake a careful examination of construction practices, structural protection techniques, and engineering, as well as a comprehensive examination of conservation needs and the natural processes affecting the shore. Understanding nearshore processes is essential to planning and the development of shorelines (Inman, 1978).

Finalizing any ordinance seeking to prevent haphazard development of the shore zone requires the expertise of engineers and geomorphologists specializing in coastal phenomena.

In addition to a comprehensive data base, the plan should include both the natural and socio-economic resources and general condition of the shore area. In planning for the shore structure section of the ordinance, it is important to examine the legal and social consequences where such protection results in significant impact on the physical and ecological aspects of the environment.

As expressed in the Coastal Erosion Element of the Great Lakes Basin Commission's comprehensive coordinated joint plan, several questions need to be asked in the construction of a plan. Specifically:

(1) Has the area in which the property is situated been mapped for its susceptibility to erosion?

The Erie County, Pennsylvania shoreline of Lake Erie was mapped early in the Coastal Zone Management effort. Various reaches were classified as low, moderate, or critical hazard dependent on the evidence of slight, moderate, or severe erosion taking place at the time of the observation. These estimates were necessarily subjective. Information generated by a planned geotechnical examination of the bluffs and beach areas will be available for incorporation into the planning effort.

(2) How fast is the erosion occurring?

Bluff recession rate data is presently available as a result of work done in 1974 (Knuth, Crowe, 1975). This data will be upgraded during 1981 as a result of a monitoring program planned as a part of a geotechnical examination of the shore zone. Erosion of the shore itself is difficult to determine. Examination of aerial photographs and old navigation charts promises to reveal more information about shore erosion (Carter, 1976). Changes in lake level can "create" or diminish the amount of beach area at a given point through time.

(3) Are there any shore protection structures nearby that might interrupt nearshore currents that carry sediment?

A shore structure inventory (Knuth, 1978) was conducted by the U.S. Army Corps of Engineers in 1978 for the Pennsylvania portion of Lake Erie. The occurrence of existing structures and the impact they have on erosion and recession is an item for further study. Some cause and effect statements can be made relative to breakwater design at Presque Isle State Park and a jetty at a Pennsylvania Fish Commission access point at Walnut Creek. The impact that additional structures may have on erosion must be considered during any planning efforts in the future.

(4) How far are existing structures from the edge of the bank or bluff?

Existing structures are located variously from the very edge of the bluff to some landward distance away. Several structures are in imminent danger of failure due to persistent recession. The Bluff Recession and Setback Act provides that all municipalities shall determine a safe setback distance from the bluff crest and provide an ordinance that can control construction in the future.

(5) Can existing structures be relocated if necessary? If relocated, how much will it cost?

The relocation of most structures on the shoreline would generally provide an expense out of proportion with the value of the structure. In many cases property boundaries are not sufficiently deep to accommodate relocation on the same site. Many structures would provide insurmountable difficulties due to design even given enough property and a more modest *relocation expense.*

(6) Is property adequately drained?

Current investigation into storm water management in Erie County will hopefully shed more light on this important element. There exists a definite cause and effect relationship between overland and interior drainage and recession rates of the bluffs saturated with ground water or eroded by runoff from beyond the bluff crest. Controlling drainage is a necessary first step in preventing or slowing recession in the future.

(7) If it is necessary, is structural protection affordable?

As mentioned elsewhere in this report, attempts at low-cost shore protection can frequently be detrimental beyond any positive effects the structure may have. The best protection is quite expensive surpassing $500 per foot of shore protected. Few, if any, individuals can provide this measure of protection and it is doubtful if the amount could be justified given current market values.

The above questions are primarily posed to provide a planner with guidelines with which to judge requests for building permits for shore protection structures. If proper answers are to be given the property owner the above serv~~ices~~es to indicate the need for additional information. To be of maximum utility the plan should answer these questions as a primary first step in the local permit process.

Essentially, each of the following needs to be addressed in the planning sequence (White, 1978):

(1) Areas potentially affected by extreme natural events must be delineated. Such hazard areas can be divided into:

- (a) bluff recession hazard
- (b) shoreline erosion hazard
- (c) shoreline flooding hazard
- (d) stream mouth flooding

(2) Estimates of vulnerability must recognize that human occupation of a vulnerable area always involves the beneficial use of a resource and the risk of possible loss.

(3) More than one adjustment should be offered to mitigate each of the above hazard factors. For example, the following range of adjustments are available to the municipality for inclusion in an ordinance or a set of regulations:

- (a) Subdivision regulations
- (b) Zoning
- (c) Acquisition of high risk erosion sites
- (d) Building ordinances
- (e) Easements

On an advisory basis the following could be offered:

(a) New or improved warning systems including preparedness plans. Effective hazards disclosure statements should be made part of any one or combination of the following:

- Environmental impact reports
- Hazard warning in deeds
- Hazard warning in mortgage agreements
- Covenants
- Law stipulating a hazard disclosure at time of sale

(b) Control and protection works information and advisory bulletins

(c) Effective participation in Federal Floodplain Insurance Programs.

In some hazardous areas, site specific investigation may be required in order to determine whether development anywhere on a given parcel would be safe. The developer could be prepared to provide local authority with a professionally prepared, site specific report which indicates that the proposed development would be safe.

An alternative to establishing an erosion plan and ordinance would be a continuation of existing coastal hazards (status quo). For example, with no increase in research and data collection, some permit applications and development proposals will continue to receive inadequate analysis and evaluation (GLBC, 1980).

An ordinance should ensure wise coastal development and also place the burden of the cost of protection on the property owner who knowingly chooses to live in a hazardous area.

STATUTORY AUTHORITY

State and local governments should exercise regulatory authority to control development in coastal hazard areas in an effort to prevent future flood and erosion damages (GLBC, Great Lakes Basin Plan, 1980).

States have the authority to grant powers to cities, towns and townships to regulate the use of land within their boundaries. In addition to building codes and zoning ordinances, the municipality may enact regulations on excavations, dumping or construction of shore structures. If the municipality has enacted a specific ordinance, shore protection works above ordinary high water fall within municipal authority. The local government then has the responsibility to see things broadly and to plan for the long term welfare of its citizens on the local level.

In Pennsylvania local governments retain the power to regulate land use and perform comprehensive planning. The Municipalities Planning Code grants local governments a great deal of discretion in exercising these powers. It is legally possible to institute new and different land controls as long as they do not violate constitutional principles. The following are some possibilities:

- Storm water management controls
- Zoning to conserve valuable natural resources

- Development controls for hazard areas

The subdivision and land development regulation may include provisions to ensure that "land that is subject to flooding, subsidence...shall be made safe for the purpose for which such land is proposed to be used, or that such land shall be set aside for uses which shall not endanger life or property or further aggravate or increase the existing menace." (Pennsylvania Municipalities Planning Code)

Zoning ordinances may include additional classification within districts "for regulation, restriction, or prohibition of uses and structures at or near...natural or artificial bodies of water, places of relatively steep grade or slope... floodplain areas and other areas having a special character or use affecting and affected by their surroundings." (Pennsylvania Municipalities Planning Code)

DAM SAFETY AND ENCROACHMENTS ACT

While not delegating specific authority to local municipalities, the Dam Safety and Encroachments Act nevertheless provides oversight to any planning elements conceived at the local level. The purposes of the Act are to:

- Provide for the regulation of dams, reservoirs, water obstructions, and encroachments in the Commonwealth, in order to protect the health, safety, and welfare of the people and property.

- Assure proper planning, design, construction, maintenance, monitoring, and supervision of dams and reservoirs, including such preventative measures as are necessary to provide an adequate margin of safety.

- Protect the natural resources, environmental rights and values secured by the Pennsylvania Constitution and conserve the water quality, natural regime, and carrying capacity of watercourses.

- Assure proper planning, design, construction, maintenance, and monitoring of water obstructions and encroachments, in order to prevent unreasonable interference with water flow and to protect navigation.

THE BLUFF RECESSION AND SETBACK ACT

The Bluff Recession and Setback Act gives local authority a specific mandate to provide setback ordinances for the construction of structures on the bluff crest. This ordinance shall be properly incorporated into any shoreline erosion ordinance. The purposes of the Act are to:

- Encourage planning and development in bluff areas which is consistent with sound land use practices.

- Protect people and property in bluff areas from the dangers and damage associated with the inevitable recession of bluffs.

- Prevent and eliminate urban and rural blight which results from the damages of bluff erosion and recession.

- Minimize the expenditures of public and private funds for shoreline protection and bluff stabilization structures and activities.

- Authorize a comprehensive and coordinated program to regulate development activities through the use of setback ordinances in bluff recession hazard areas, designed to prevent continuing destruction of private property and structures.

- Encourage local administration and management of bluffs consistent with the Commonwealth's duty as trustee of natural resources, and the people's constitutional right to the preservation of the natural, scenic, aesthetic and historic values of the environment.

THE TAKING ISSUE

The taking issue is relevant only in a small portion of land use control decisions. In fact, land use controls should withstand a taking challenge where:

- The owner of the land is left with a reasonable, profitable use, even though it is substantially less than the most profitable use.

- The restriction can be shown to be necessary to protect the public health, safety or welfare (environmental hazards such as floods, landslides, sinks, limited water supplies, susceptibility to erosion and runoff damage, and temporary restrictions to protect mineral resources are the easiest to document).

- The local government has not attempted to use zoning controls where it should actually purchase land for a given activity such as public recreation.

NEED FOR PLAN

There is an obvious need for a comprehensive planning effort for the placement of erosion control structures and development of lands adjacent to or within a hazard area. As erosion continues as a threat to individual property owners the response is generally to prevent losses of property by the construction of various shoreline protection devices. The crucial issue is the extent to which a landowner may take protective measures without incurring a liability for injury to his neighbor. (Hildreth, 1980)

In an attempt to control haphazard development in hazard areas developmental controls are obviously needed. Weak controls will create indecision in response while too strict controls could be challenged as a governmental "taking" of private property without just compensation. A challenge would probably succeed if scientific accuracy is lacking in the information relied upon in determining developmental controls. Two aspects of Common Law apply.

(1) The Common Enemy Doctrine

The Common Enemy Doctrine states that a landowner may do anything to repulse surface waters from his land without liability for damages to others caused by his actions. A neighboring property owner has the right to protect his property as well. Any injury to neighboring land is said to be *damnum absque injuria*. A property owner may apply this law only in the face of imminent harm.

(2) Civil Law

Civil Law states that an upstream owner may not impede the downstream flow; applicable in the case of shore structures when littoral drift is considered as flow. A property owner could collect damages as a result of such interference by his updrift neighbor and could enjoin unreasonable behavior.

The rights of property owners are determined by assessing all of the pertinent data including:

- Surrounding circumstances of the particular issue,
- Nature of the improvement,
- Extent of interference with surface water,
- Value of improvement compared to injury to a neighbor, and
- Foreseeability of the harm. (Hildreth, 1980)

To be successful a regulatory plan must recognize the rights of all citizens. In addition it must respect the natural processes active in bluff recession and beach erosion. The complicated nature of the interaction of natural processes and human occupance is the essential element in any ordinance written for hazard zone occupance.

OBJECTIVES OF THE ORDINANCE

To be successful a shore erosion ordinance must act to guide both public and private decisions related to shore zone occupance and, as a result, realize the goals and objectives of the plan.

The plan should have a positive rather than a negative or restrictive tone. The emphasis should be placed on guiding development in areas where such development will not create a negative impact on the environment or be affected by environmental changes.

The following can be considered as objectives and are gleaned from various sources (McKinney, 1980, The Conservation Foundation, 1980, Michigan Department of Natural Resources, 1973).

(1) New Development in the shorelands should be limited to those activities and facilities specifically requiring a shoreland location.

(2) Permissible development should be planned, designed, constructed, and operated and maintained as to harmonize with the capacities and tolerance limits of the natural shoreland ecosystem.

(3) Public policy should foster and facilitate to the maximum extent possible the acquisition of key shoreland environmental areas into the public ownership and their management for present objectives.

(4) Restrict construction of new buildings in the shore zone to remove developmental pressures.

(5) Provide information about protective structures for eroding shorelands.

(6) Manage coastal watersheds for least alterations of natural patterns of stormwater runoff.

(7) Preserve ecologically vital areas such as edge zones and beach areas.

(8) Preserve the integrity of coastal geologically protective structures--beaches, erodible banks and bluffs.

(9) Protect the configuration of coastal water basins against adverse alterations (dredging or cutting).

(10) Protect coastal waters from pollution.

(11) Protect public health and welfare with regard to dangers associated with coastal hazard areas.

(12) Provide a long-term, cost effective strategy for the reduction of infrastructure losses to developed coastal areas.

(13) Protect and enhance the natural coastal resource systems of the beach bluff interface so as to obtain maximum level of natural storm protection; the environment of recreational beaches and environmental quality as related to these ecosystems should also be realized.

(14) Provide increased opportunity for the general public to have unrestricted beach access.

(15) Minimize expenditures of public monies for costly erosion protection structures.

(16) Protect the land water interface by controlling shoreline alterations.

(17) Control building sites, placement of structures and land uses through:

(a) separating incompatible land uses

(b) prohibiting certain uses detrimental to the shoreland area.

(18) Preserve shore cover and natural beauty through:

(a) restricting the removal of natural shoreland cover

(b) regulating shoreline encroachments by structures

(c) controlling shoreline excavation.

(19) Provide an information service to prospective owners warning of the erosion hazard that may exist at the particular site.

SAMPLE EROSION HAZARD ORDINANCE

The following erosion hazard ordinance is an adaptation after D. A. Yanggen's work for the Wisconsin Coastal Zone Management Program. As a working model, it incorporates many of the elements that would have prime consideration for the Pennsylvania portion of the Lake Erie Shore. It is well known that there are great similarities among all coastal Great Lakes States.

SAMPLE EROSION HAZARD ZONING PROVISIONS

The following coastal erosion hazard provisions are designed for inclusion in a municipal comprehensive zoning ordinance. These sample coastal erosion hazard provisions are more detailed and elaborate than those a local government would likely include in its own zoning ordinance. Setting forth a full array of provisions gives a better picture of possible items for inclusion in a particular ordinance. More detailed provisions and accompanying commentary give insight into some of the factors that should be considered in administering a simpler ordinance. Some of the provisions could be adopted as an erosion hazard policy plan which would be incorporated into the regulations by reference. The choice of the most appropriate provisions will depend on the local land use policies, the type of hazard, and the data available.

1.1 Finding of Fact

The coastal erosion hazard areas of   are subject to substantial erosion. These hazard areas have been identified on the basis of studies of shoreline recession, stable slope angles, and other engineering and geological studies and principles. Improper land use within these areas causes erosion damages in the form of property losses, environmental degradation, and the impairment of public rights in navigable waters. These erosion damages are the result of: (1) structures placed in areas which will be undermined by erosion; (2) land use activities that accelerate erosion; and (3) improperly designed, installed, and maintained protective measures which accelerate erosion on nearby properties and cause environmental damage.

1.2 Statement of Purpose

It is the purpose of these regulations to protect the public health, safety, and general welfare and to reduce erosion damages by: (1) establishing a setback line designed to minimize losses over a   year period; (2) restricting uses which are vulnerable to erosion damage; (3) regulating land disturbance, stormwater drainage and other activities which increase erosion; and (4) requiring that proposed protective works are properly designed, installed and maintained.

2.0 Lands to Which Regulations Apply

(Option #1) These regulations shall apply to all lands which are within   feet of the ordinary high water mark of Lake Erie.

(Option #2) These regulations shall apply to all lands within the erosion hazard areas as shown on the final coastal zone boundary map. Where specific distances from the ordinary high water mark are described on the map, these distances shall control.

3.0 General Provisions

3.1 Effect on Other Provisions

3.11 These provisions are intended to supplement and not to repeal other applicable regulations; however, where these provisions impose greater restrictions they shall control.

3.12 No lot shall hereafter be created, subdivided or otherwise established without sufficient depth to accomodate structures in compliance with these provisions.

3.2 Warning and Disclaimer of Liability

These provisions are considered to be the minimum reasonable requirements necessary for reducing erosion damage for a   year period. These requirements are based upon engineering, geological, and other scientific studies and principles. Faster rates of erosion may occur. Erosion rates may be increased by natural causes such as major storms or high lake levels or by manmade causes such as the construction of erosion control structures or land disturbing activities. These regulations do not guarantee or warrant that development in compliance with its terms will be free from all erosion damage. Reliance on these regulations shall not create liability on the part of the enacting government or any officer or any employee thereof.

4.0 Erosion Hazard Setback Lines

Within the boundaries of the erosion hazard areas established by Section 2.0 the minimum erosion setback shall be as follows:

4.1 Bluffs

4.11 A stable slope angle setback shall be established at a ratio of 2 1/2 feet horizontal distance to every one foot vertical distance. The measurement shall be made from the ordinary high water mark perpendicular to the shoreline. There shall be two such measurements made for every 100 feet of shoreline at points not less than 50 feet apart. The stable slope angle setback shall be a line connecting these two points or such line extended. In cases of an irregular shoreline or where the lots are not perpendicular to the shoreline, the Zoning Administrator may require that additional points of measurement be used to determine the stable slope angle setback.

4.12 An additional recession rate setback shall be measured from the stable slope angle setback. The year recession rate shall be calculated using the average annual recession rate indicated on the official map. Where no recession rate is known, the safety factor shall be calculated by assuming a foot per year average annual recession rate.

4.13 A "bluff" is that segment of the shoreline which is 10 feet or more in height and which has a rise of 10 feet or more vertical distance in less than 25 feet horizontal distance.

4.2 Ravines

A stable slope angle setback shall be measured at a rate of 2 1/2 feet horizontal distance to every one foot vertical distance for all ravines 10 feet or deeper. The measurement shall be made from the center of the deepest part of the ravine.

4.3 Dunes and Beaches

4.31 A recession rate setback shall be measured from the ordinary high water mark. The year recession rate shall be calculated using the average annual recession rate indicated on the official map. Where no recession rate is known, the safety factor shall be calculated by assuming a foot per year average annual recession rate.

4.32 "Dunes and Beaches" are those erodible segments of the shoreline which are not in bluffs.

4.4 There shall be a minimum setback of 75 feet from the ordinary high water mark in all cases. Ordinary high water mark means the point on the bank or shore to which the presence or action of surface water is so continuous as to leave a distinct mark such as by erosion, destruction or prevention of terrestrial vegetation, predominance of aquatic vegetation, or other easily recognized characteristic. Where the bank or shore at any particular place is of such character that it is difficult or impossible to ascertain where the point of ordinary high water is, recourse may be had to the opposite bank of a stream or to other places on the shore of the lake to determine whether a given stage of water is above or below the ordinary high water mark.

4.5 The ordinary high water mark and setback lines shall be determined by the Zoning Administrator on the basis of data submitted by a licensed surveyor or on the basis of a field inspection. Where conflicts arise the Zoning Officer shall contact the Department of Environmental Resources to make an official determination of the ordinary high water mark.

4.6 The Zoning Agency may issue a conditional use permit as provided in Section 6.0 allowing modification of the erosion hazard setback upon presentation by the applicant of acceptable engineering studies documenting (1) lower recession rates, (2) more stable slope conditions, (3) plans for structural protection against wave attack, (4) plans for stabilization of the bluff or shoreline.

5.0 Regulation of Uses Within Erosion Hazard Setbacks

These provisions supplement the underlying zoning which remains in effect to the extent its provisions are more restrictive. The following uses are prohibitive uses, permitted uses and conditional uses within the erosion hazard setbacks established by Section 4.0.

5.1 Prohibited Uses

5.11 Residential, institutional, commerical, industrial, agricultural and public buildings designed for permanent use at the proposed location.

5.12 Septic tank systems and other on-site waste disposal facilities.

5.2 Permitted Uses

5.21 Open space uses

5.22 Storage of portable equipment, machinery or materials

5.23 Accessory buildings which can be easily and economically moved, such as storage sheds

5.24 Minor structures such as driveways, walkways, patios, and fences

5.3 Conditional Uses

5.31 Buildings and structures which are readily removable in their entirety provided they are so located and constructed that they may be removed prior to erosion damage

5.32 Other uses similar to those permitted in 5.2 and 5.3 which are determined by the Zoning Administrator to be compatible with the intent and purpose of these regulations. (See also 6.0 Regulation of Shoreline Protection Devices and Land Disturbances.)

6.0 Regulation of Shoreline Protection Devices and Land Disturbances

6.1 The following shoreline protection activities are conditional uses:

6.11 All structures or deposits, which are shoreline protection devices, below the ordinary high water mark.

6.12 The placement of shoreland protection devices above the ordinary high water mark

6.13 "Shoreline protection devices" means breakwaters, groins, revetments, seawalls, bulkheads, rip rap, deposition of materials such as stone and concrete rubble, bluff stabilization projects and similar measures.

6.2 The following land disturbing activities are conditional uses when conducted within   feet of the ordinary high water mark or the erosion hazard setback, whichever is the greater distance.

6.21 Alteration of more than   square feet of wetlands. For purpose of this regulation "wetlands" are defined as those areas where water is at, near or above the land surface long enough to be capable of supporting aquatic plants, and which have soils indicative of wet conditions.

6.22 Filling or grading on all slopes of 20% or more

6.23 Filling or grading of more than   square feet on slopes of 12-20%

6.24 Filling or grading of more than   square feet on slopes of 12% or less

6.25 Dredging, construction or other work on any artificial waterway, canal, ditch, lagoon or similar waterway

6.26 Removal of more than   square feet of vegetation. Where vegetation is removed it shall be replaced, as far as practical, with other vegetation that is effective in retarding runoff, preventing erosion and preserving natural beauty.

7.0 Conditional Uses

7.1 General

Conditional uses are uses which may create special problems and hazards if allowed as a matter of right. Whether such uses can be appropriately established depends on the facts and circumstances of the particular situation. The conditions which may be attached to development permission can, in some instances, avoid adverse effects on adjoining property or the public welfare.

Conditional uses are allowable only upon written approval by the Zoning Agency authorized to issue conditional use permits. The Zoning Agency may, after public notice and hearing, permit, deny, or permit the use subject to attached conditions. In passing upon a conditional use the zoning agency shall specify the information to be supplied, evaluate the proposed use according to specified standards, and attach appropriate conditions to development permission.

7.2 Procedure

7.21 Any use listed as a conditional use shall be permitted only upon application to the Zoning Administrator and issuance of a Conditional Use Permit by the Zoning Agency.

7.22 Before passing upon an application for a Conditional Use Permit the Zoning Agency shall give notice and hold a public hearing.

7.23 The Zoning Agency shall, when appropriate, seek technical review assistance from the Department of Environmental Resources or the U.S. Army Corps of Engineers, and other agencies having relevant expertise.

7.3 Information to be Supplied

The Zoning Agency may require the applicant to furnish the following data which it finds pertinent and necessary for its determination:

7.31 A plat of survey prepared by registered land surveyor, or other maps drawn to scale showing the location and dimensions of: property boundaries, the ordinary high water mark, contours of the site, required and proposed yards and setbacks, existing and proposed vegetative cover and landscaping, existing and proposed buildings, structures, driveways, parking and loading areas and streets, existing and proposed areas for the storage of equipment, machinery and materials, areas of proposed grading, filling, dredging and vegetative removal, and existing and proposed methods of controlling stormwater runoff and problem groundwater conditions.

7.32 Plans of buildings or other structures, sewage disposal facilities, water supply facilities.

7.33 A description of the method of operation of industrial and commercial uses.

7.34 A report, prepared by a registered professional engineer, certifying that the site is or can be made suitable for the proposed development.

The report shall consider, describe, and analyze the following:

(1) past, current, and future wave induced erosion based upon recession rates and wave energy calculations;

(2) geologic conditions including the soils and stratigraphy of the site and an analysis of the properties and stability of the materials present;

(3) ground and surface water conditions and variations including changes that will be caused by the proposed development;

(4) plans and specifications for bluff and shoreline stabilization measures and plans and specifications for measures to protect against wave erosion, including the estimated life of such structures, their cost, the maintenance required, and the effect on nearby properties and the shoreline of the lake environment;

(5) where a modification of the erosion hazard setback is proposed the minimum setback required to provide a reasonable degree of safety to the proposed use for a period of   years;

(6) methods to be used to control surface erosion and storm water runoff during and after construction;

(7) the elevation of the 100 year flood and storm surges where the site is subject to flooding

7.35 Other pertinent data necessary to determine if the proposed use and location is consistent with the requirements of these regulations.

7.4 Standards Applicable to all Conditional Uses

In passing upon a conditional use, the Zoning Agency shall evaluate the proposed use in terms of:

7.41 The erosion and flooding hazard

7.42 The need of the proposed use for a shoreline location

7.43 Compatibility with nearby land uses

7.44 Adequacy of proposed waste disposal and water supply systems

7.45 Location with respect to existing or proposed roads

7.46 The demand for public services engendered and the adequacy of existing services to meet the demand

7.47 Protection of the scenic beauty of the shoreline

7.48 Protection of public rights in navigable waters

7.5 Conditions Which May be Attached to Conditional Uses

7.51 Upon consideration of the factors listed above, the Zoning Agency may attach such conditions, in addition to those required elsewhere in this ordinance, that it deems necessary to further the purpose and intent of these regulations. Such conditions may include, without limitation because of specific enumeration: bluff and shoreline stabilization measures; measures to protect against wave attack; control of groundwater seepage; revegetation and landscaping; control of surface water runoff; the continued and regular maintenance of the above listed measures; design and construction of structures to be moveable in accordance with accepted architectural or engineering standards; the removal and relocation of uses prior to erosion damages; type of construction; construction commencement and completion dates; performance standards and operational controls; dedication of land; sureties, and performance bonds; deed restrictions; and other measures designed to ensure the satisfactory location and maintenance of uses in accord with the purpose and intent of these regulations.

7.52 When a conditional use is approved a record shall be made of the land use and structures permitted, and the conditions attached to such permission. Violations of conditions attached to a conditional use shall constitute a violation of this ordinance. The Zoning Agency may, after notice and hearing and opportunity for corrective action, revoke the permit and seek a forfeiture or injunctional order as provided by law.

7.53 All legal existing uses which would be classified as conditional uses if they were to be established after the effective date of this ordinance or its amendment are hereby declared to be conforming conditional uses to the extent of the existing operation only. Any addition, alteration, extension, or any other change in the conditional use procedures as if such use were being established anew.

8.0 Non-conforming Uses

The lawful use of a building or premise existing at the effective date of this ordinance or its amendment may continue in the same manner and to the same extent subject to the following requirements:

8.1 Routine repairs and maintenance are permitted.

8.2 No alterations, additions, or expansions shall occur which increase the dimensional nonconformity within the erosion hazard setback unless a variance is obtained as provided in Section 9.0.

8.3 The use of any vacant lot or parcel shown on a recorded subdivision plat, assessor's plat or a conveyance, recorded in the office of the Register of Deeds, which does not conform to the erosion hazard setback shall be permitted only upon the issuance of a variance by the appropriate Board.

8.4 The other provisions of the ordinance relating to nonconforming uses and the provisions of are complied with.

9.0 Variances

A variance from the erosion hazard setback may be granted by the Board of based upon the following standards:

9.1 No variance shall be granted which would have the effect of allowing in any district a use not permitted in that district.

9.2 No variance shall be granted which would have the effect of allowing a use of land or property which would violate state laws or administrative rules.

9.3 A variance may be granted where strict enforcement of the terms of this ordinance results in unnecessary hardship and where a variance will not be contrary to the public interest, and will allow the spirit of the ordinance to be observed, and substantial justice done.

9.4 Conditions shall be attached in writing to all approved variances where such conditions will achieve compliance with the standards of this ordinance. Such conditions may include:

9.41 The proposed use is located as far landward of the erosion hazard setback as is practical.

9.42 Septic tank systems and other on-site waste disposal facilities are placed landward of the principal structure

9.43 The proposed structure is designed, constructed, and located so as to be moveable to a safe location prior to erosion damage and a deed restriction is recorded requiring removal.

9.44 Those conditions which may be attached to conditional uses as specified by 7.5.

SUMMARY CRITERIA: MODEL ORDINANCE

The comprehensive plan and companion ordinance for erosion control will contain the following:

- Public expenditures for coastal hazard management efforts will be reduced; i.e. with a decrease in the amount of hazard prone development, there will be a concomitant decrease in government effort to aid in flood or erosion prevention or mitigation.

- The quality of the coastal environment should be enhanced. Properly planned and sited development would in many cases, obviate the need for structural protection. Relatively more shoreline would remain in an unprotected, natural condition.

- Shoreline occupancies that will permanently degrade sensitive land-water environmental interfaces should not be permitted. Changes considered may be due to land development practices or the nature of the subsequent human use.

- Land development and construction operations should not permanently degrade sensitive land-water environmental interfaces. Temporary degradation of conditions affecting only the renewable or easily replaceable life forms should be permitted.

- Proper federal and other permits for construction must be obtained. Penalties should be established for violation of this criterion and violators should be legally and enforceably responsible for restoration of pre-violation natural conditions.

PERMITS

At the real risk of adding another layer to the already weighty permit structure, the municipality should consider a permit system for the construction of structures designed to ameliorate erosion hazard. To assure that all parties in the shoreline areas are considered, there needs to be a comprehensive plan whereby a municipality can regulate development in the best interests of all concerned.

Such structures are regulated by the Corps of Engineers to assure that structures in, or adjacent to, waterways do not impede navigation. Permits required by the state generally provide for control of structures resting on, or affecting, Commonwealth waters. A local permit could and should regulate structures to ensure that the sensitive shore areas are not impacted adversely by the addition of erosion control structures.

The decision by the property owner to provide a structural alternative to the erosion hazard has selected from one of the following four choices:

- Pay the high cost of proven, engineered structures
- Devise a low-cost alternative that offers temporary protection at best,
- Sell the property thereby transferring the problem, or

- Do nothing.

Since the alternative most frequently chosen is a low-cost structure, the municipality has the responsibility to regulate the construction to assure the health, safety and general welfare of all.

Most of the protective works on the Great Lakes have been constructed by private shore owners. Many of these structures have not been properly designed and do not adequately protect the shorelines and, in some cases, can aggravate erosion in their vicinity. (Environment Canada, 1973)

It should be accepted that erosion can and should only be controlled in isolated locations, prudently selected. It should also be accepted that such control shifts the damage from one area to another.

In establishing standards for protective structures, the community should ensure that they are compatible with federal and state criteria. In addition, such standards should provide additional restrictions to fulfill the responsibility as a local government but should be clearly expressed. If the process for reviewing applications for permits cannot be made more expedient and predictable, some of the basic environmental protections are threatened by lack of adherence to ambiguous and superfluous regulations. (DeHart, 1979)

It should be noted that there is a certain risk implied in granting a permit. For example, a California Superior Court decision has held that a county is responsible for private property damage resulting from development in a hazardous area for which the county had issued a permit. (NOAA, 1976)

The decision to issue a permit is based on an evaluation of the possible impact of the proposed action or activity on the public interest as a result of interest not only in protection of property but in protecting resources as well.

The benefit which may reasonably be expected to occur from the proposal must be balanced against its reasonably forseeable detriment. All factors which may be relevant to the proposal should be considered; they are:

- Conservation
- Economics
- Aesthetics
- General Environmental Values
- History Values
- Fish and Wildlife Values
- Land Use Classification

- Navigation
- Recreation
- Food Production
- Water Supply
- Water Quality
- Energy Needs
- Safety
- Needs and Welfare of the Public

Additional to the cost of capital construction then are the indirect and intangible costs of social, environmental and aesthetic disruption. Some present structures, if designed properly, cost more than the land is worth. Very little cost-benefit analysis is taking place. Erosion damages continue to increase and strategies depending solely on structural alternatives have had little success.

THE ISSUANCE OF GENERAL PERMITS

A model erosion control plan or ordinance ought to spell out the kinds of activities taken as a group that might fall under the concept of the general permit. Some regulatory programs have issued broad general permits covering new construction of certain structures within their jurisdiction while others have looked to in-depth, site specific studies to determine permitting problems. The overall objectives of a general permit can:

- Result in issuance of a general permit,
- Be economical when compared to future savings in manpower,
- Protect from adverse impacts if generally permitted construction is taking place, and
- Be accepted and generally understood by the general public.

And the advantages include:

- Provides definite and positive approach to assisting regulatory agencies,
- Reduces processing time,
- Ensures orderly development,
- Improves respect and awareness, and
- Protects the aesthetics of the coastal zone.

It should be clear, however, that a general permit is issued only if and when the proposed action meets all the criteria for that particular type of action. Deviation from the generally permitted design will be cause for site specific examination.

APPENDIX I

BIBLIOGRAPHY

BIBLIOGRAPHY

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APPENDIX II

SOME LOCAL EXAMPLES OF STRUCTURAL CONTROL TECHNIQUES

Figure A-1

Located in an area off Route Five in Erie County at Woodmere, the site has been experiencing rapid shoreline retreat and erosion at the toe of the bluff. The principal reason is elevated water levels since 1973. As can be seen in the photo, the property owner has attempted to mitigate his losses by the application of debris consisting of tree trunks, concrete rubble, and stone. Some attempt to confine the debris is clearly apparent. A concrete wall has failed. This is a rather typical example of individual response to the erosion problem. Generally the high cost of proper design and construction is beyond the means of this property owner as it is for so many others. The result of such placement is visual blight and a very temporary ameilioration of the problem. (See section I)

Figure A-2

Located in the Baer Farm Estate, this cottage, like so many others in the area, has been increasingly exposed to storm waves and high water levels. That the forces associated with storm waves is not understood is the rudimentary structure (bulkhead?) constructed as a defense measure. The structure did not live past the first storm. Constructed of railroad ties, this type of defensive measure is a total waste of time. Perhaps it gave the owner a small measure of comfort in the knowledge that he tried something. It certainly reveals a lack of information that should now be more generally available.

Figure A-3

As mentioned in Section II, groins are the preferred type of remedial measure used in Erie County to prevent erosion of beach materials and to protect property. This series of groins was constructed by property owners in Millcreek Township to protect beaches and to preserve a narrow strand of developable land. High water levels and incremental losses have put these cottages in jeopardy. At the time the buildings were constructed water levels were far below present levels burying a significant portion of beach. In addition to the groins, three of the owners have constructed bulkheads as minimum protection against anything larger than a five foot wave event.

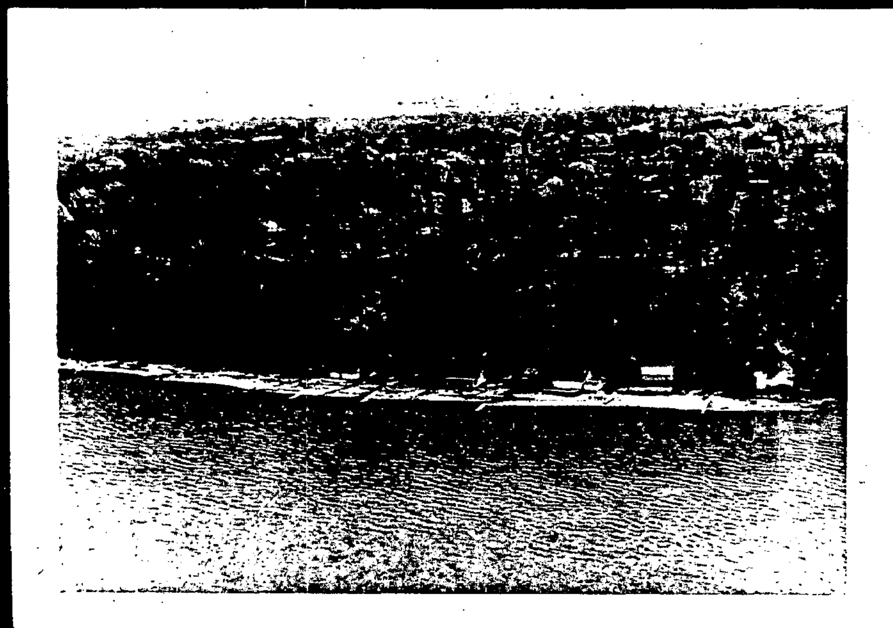

Figure A-4

The structure at the edge of the bluff is clearly in imminent danger of loss to bluff recession. Coupled with the need to provide a minimum recreational beach at the camp (Eriez-on-the-Lake) a groin was constructed to accumulate sand. It is apparent that the groin is serving to accumulate some sand producing a measure of protection at the toe of the bluff. However, equally apparent is the starved condition of the beaches downdrift (left of the groin in the picture). The beaches downdrift exhibit wave cutting in the foreshore. The effects are not as pronounced as they might be. While the bluff downdrift is receding the rate is not out of character with the bluff being protected by the groin.

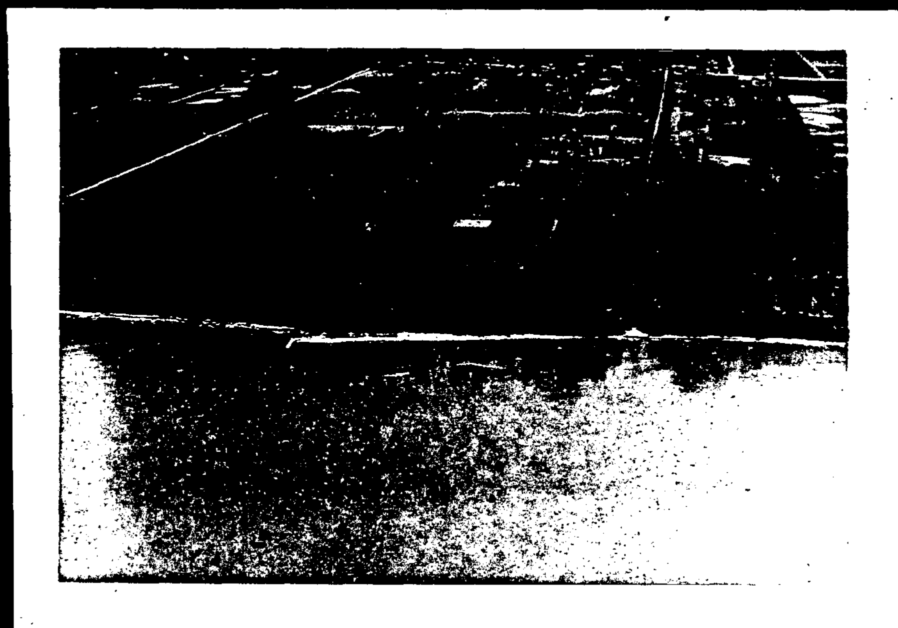

Figure A-5

This gabion was constructed at Kelso Beach, Millcreek Township as a low-cost, short-term solution to beach erosion. The baskets were filled with native stone. The gabion survived one season and was not replaced by the owner. While the low cost of such structures is attractive, the user most often does not maintain the structure over time. The obvious explanation is that the relative non-success of such structures beyond one season does not justify reconstruction or maintenance. In the meantime, the effects produced on shore equilibrium are significant. (See Section II)

Figure A-6

Also located at Kelso Beach is this cast concrete groin. The structure is tied back in the backshore and has withstood several seasons of storm waves. A possible explanation for its success is the generally good supply of sand in the drift system at this location. In addition, the presenece of offshore bars serve to "trip" storm waves and reduce the energy receipt on shore.

Figure A-7

These bulhead and groin combinations are the rpsult of individual response by the owners to protect year-round residences at the foot of Powell Avenue in Millcreek Township. They are generally haphazard affairs accomplished with limited dollars. The predominate material behind the groins is shingle-sized fragments eroded from the bedrock at or near water level on site and up drift. The accumulation of this larger sized material has assisted in protecting valuable property perched precariously at the zone between the high bluffs and the beach area. It is an area of high risk as lake levels continue high. Structural response is the only response available. Cost is the deterrent.

Figure A-8

Located near the mouth of Godfrey Run in Girard Township, the structure is fairly typical of groins constructed in the western part of the county. The initial structure was poured in place and subsequently improved by extensions of height and length with pre-cast concrete blocks. An accumulation of material can be seen on the updrift side. The negative influences are apparent on the downdrift side. A starved beach has enabled storm waves to attack the base of the bluff, destroying stability. Such structures almost always cause negative impacts downdrift. See Section II.

Figure A-9

Attempts to mitigate the downdrift effects of groins consist of placing rubble on the downdrift side to prevent losses of beach material. The procedure illustrates that tampering with beach equilibrium is going to result in negative impact followed by additional costs either on-site or on sites downdrift. (See Section II)

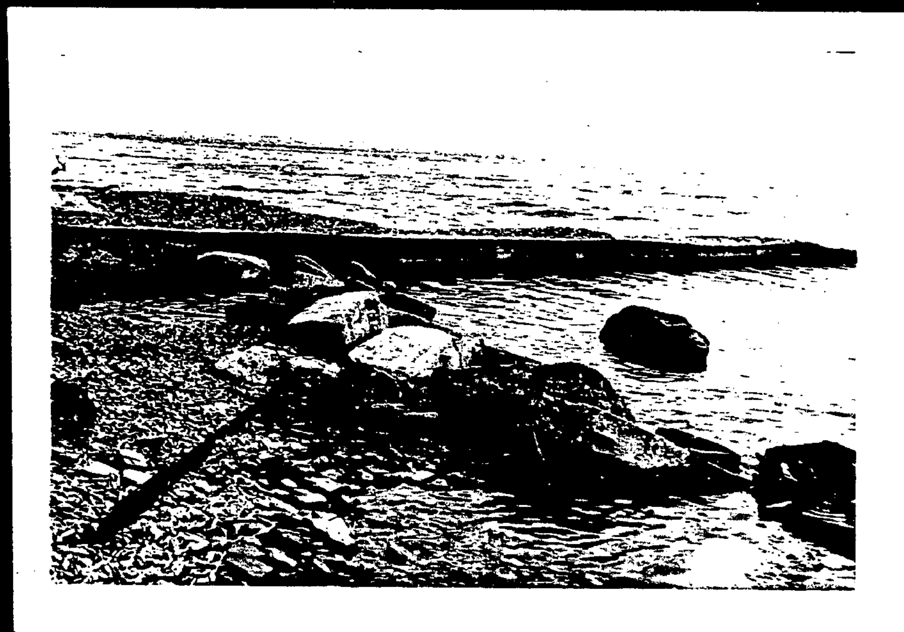

Figure A-10

A more innovative approach to bulkheading was attempted at Freeport, Northeast Township. The barrels are tanks cut in half, tied together, firmly founded, and backfilled. Bulkheads in low lying areas with no pressure from mass wasting behind, have a good chance of survival if properly designed. See Section III. This particular structure has survive eight seasons with a minimum of maintenance consisting og backfilling the structure. As stated in Section I, such structures preclude beach building at the lakeward side. The structure then, must be strong enough to survive without the protection of a well developed beach.

Figure A-11

At the Gunkle residence in Girard Township a groin constructed by the up drift property owner has produced a negative impact on the Gunkle property. Combined with a starved beach, bluff instability has produced a hazard to the high-cost dwelling located at the edge of the bluff crest. Unfortunately, high bluff conditions preclude remedial measures on the bluff face. One alternative would be to construct an additional groin on the downdrift side of the property. It is not known if there is a sufficient supply of sand in the system to feed an additional structure. See Section II.